BRUSH CONTROL ON FOREST LANDS

with emphasis on promising methods for the Pacific Northwest

(A review of selected references)

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By

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INTRODUCTION

Brush[2] encroachment on forest land is greatly reducing the amount of wood grown in forests of the Pacific Northwest. Reliable estimates show that brush has reduced the productivity of more than one-fourth of the forest land of southwestern Oregon. Red alder[3] alone, which is a commercial tree on some areas but a weed species on others, accounts for poor conifer stocking on another two million acres in the Douglas-fir region of Oregon and Washington. Brush also occupies a large area of ponderosa pine land east of the Cascade Range.

1/ The authors are indebted to many people and organizations, including foresters serving in many different capacities, college professors, and chemical companies. Special acknowledgment is due Harold R. Offord of the blister rust control division, Region 5 U. S. Forest Service for assistance in the preparation of table 1, Appendix, and for review of the manuscript.

2/ The term "brush" is used to include all undesirable herb, shrub, and tree species.

3/ Common names will be used throughout this review except where suitable ones are unavailable. See Appendix (table 2).

Many besides foresters are plagued by brush or engaged in brush-control research. Utility companies, state and county highway departments, universities and colleges, chemical companies, and range managers are aggressively trying to learn how to control troublesome brush species cheaply. This paper briefly reviews results of some of these efforts and presents a bibliography of selected references. Main emphasis is placed on methods that may prove useful to foresters of the Northwest. Information and examples, however, have been drawn from all over the United States and from some foreign countries. Publications containing the most pertinent findings have been cited directly in the text. The index to the bibliography provides the reader who is interested in greater detail a further opportunity to locate the information he wants.

Four principal methods of controlling brush are: (1) chemical, (2) mechanical, (3) burning, and (4) biological. The discovery of potent new herbicides in recent years has directed attention to chemical techniques. Situations will be encountered, however, where each of the four methods or combinations of them are effective.

CHEMICAL METHODS

Some typical uses of chemicals for controlling brush on forest lands are to: release natural and planted trees from overtopping brush, prepare areas for natural or artificial regeneration, kill large cull trees, thin young stands, keep brush from encroaching on road rights-of-way, and control blister rust by killing ribes. While preferred chemicals and methods have been worked out for many of these jobs, the whole field is in a state of rapid development. New methods and chemicals are constantly being discovered.

The Chemicals

Ideal chemical herbicides should readily kill unwanted brush or weed trees without damage to desirable trees and be cheap, easy to apply, noncorrosive to metals, and nontoxic to animals and humans. So far, 2, 4-dichlorophenoxyacetic acid (2, 4-D), 2, 4, 5-trichlorophenoxyacetic acid (2, 4, 5-T), and ammonium sulfamate (Ammate) most nearly meet these specifications and are most used by foresters.

2, 4-D and 2, 4, 5-T

2, 4-D and 2, 4, 5-T are synthetic plant hormones capable of killing or greatly retarding growth of many broad-leaved and coniferous plants. The chemicals are usually absorbed into leaves or stems

but may also enter through roots. Movement inside the plant is closely associated with sugar movement. The chemicals tend to accumulate at such places as growing tips or roots where sugars are being used or stored. Once inside the plant, 2, 4-D and 2, 4, 5-T cause a twisting and curling of petioles and leaves, the result of cell elongation. Basic physiological processes are also interrupted.

Two outstanding characteristics of 2, 4-D and 2, 4, 5-T are the small amounts required to kill or damage many plants and the translocation of these herbicides inside the plant. In practical terms this means that only a few drops or particles on most leaves will often be effective.

Foresters have seldom used 2, 4-D or 2, 4, 5-T in the acid state. Instead salt or ester formulations are used. The esters are formed by chemical union of 2, 4-D or 2, 4, 5-T acid and an alcohol. In form, esters may range all the way from light oils to greases with a low melting point. Usually commercial ester formulations are oily liquids that will either dissolve in other oils or disperse in water. There is some tendency for the lighter esters, such as methyl, ethyl, isopropyl and butyl to volatilize like gasoline. The heavier esters such as the propylene glycol butyl ether group and butoxy ethanal are much less inclined to vaporize. They are often referred to as low-volatile esters. Commercially available salts are soluble in water and do not easily volatilize.

The ester formulations of 2, 4-D and 2, 4, 5-T have proved to be more effective on woody plants than the salt forms used earlier. Robbins and collaborators (205) [4/] further point out that some low-volatile esters are distinctly superior to more volatile forms in both absorption and translocation. Crafts (51) explains this is true because low-volatile esters possess the best balance of solubility in water and oil. Oil solubility is necessary for penetration of the waxy cutinized layer on most leaves, but water solubility is necessary for movement from cell to cell inside the plant. Crafts (51) also points out that 2, 4-D and 2, 4, 5-T in the acid state have these same properties, but Moss (175) encountered difficulty using a suspension of 2, 4, 5-T acid in oil because of its tendency to settle out.

Despite the general conclusion that low-volatile esters are best for woody plant control, volatile esters or amine salts have sometimes been used to good advantage:

4/ Underlined numbers in parentheses refer to literature listed in the bibliography.

1. Kissinger and Hurd (125) report from Wyoming that isopropyl and amyl esters of 2, 4, 5-T gave the most sagebrush control per dollar.

2. McIlvain (162) reports that on a cost basis the two types of esters are about equal for use on shinnery oak.

3. Moss and associates (177) report very promising results with an amine formulation of 2, 4, 5-T for late-season spraying of Sierra gooseberry, and Emrick and Leonard (75) report excellent results with an amine 2, 4-D on interior live oak.

Both 2, 4-D and 2, 4, 5-T are selective herbicides. When used at recommended herbicidal dosages, they damage or destroy some plants but not others. Some plants are affected by both herbicides, others by only one, and still others by neither. In general, 2, 4-D is more specific than 2, 4, 5-T. As an example, Offord and collaborators (187) report that 2, 4, 5-T caused systemic damage to all 33 species of ribes on which it was tried, but only 5 of the 33 were significantly damaged by 2, 4-D. Evidence of a differential response within species was also found. One variety of Sierra gooseberry was easily killed by 2, 4-D while a second variety of the same species was most easily killed by a mixture of 2, 4-D and 2, 4, 5-T.

When 2, 4-D and 2, 4, 5-T are used together, complementary action between the two is normally not expected. There are a few instances, however, where such action has occurred. Timmons and Lee (223), for example, report better results on common chokecherry with a mixture of the two chemicals than with either alone. Other times 2, 4-D may actually have lessened the effect of 2, 4, 5-T. Thus, Offord and co-workers (187) report a poorer kill of some ribes species with mixtures of 2, 000 parts per million (p.p.m.) 2, 4-D and 1, 000 p.p.m. 2, 4, 5-T than with 1, 000 p.p.m. 2, 4, 5-T alone. Adding chemicals like trichloroacetic acid (TCA), Ammate, and pentachlorophenol to the hormone chemicals offers considerable promise. Such mixtures have sometimes produced far better results than 2, 4-D or 2, 4, 5-T alone. Freed (82) believes TCA is especially useful for this purpose but thinks the general field deserves more investigation.

2, 4-D and 2, 4, 5-T are usually considered to be nonpoisonous to humans and animals. However, when mixed with other substances, they may prove to be somewhat toxic. Grigsby and Farwell (8) state that domestic animals are not attracted to areas sprayed by 2, 4-D or 2, 4, 5-T. However, Freed (82) says the palatability of sprayed

plants ordinarily not eaten is increased, and Rudolf (207) points out that herbicides may indirectly poison livestock because poisonous plants such as common chokecherry may be made palatable.

Ammonium Sulfamate

Ammonium sulfamate (Ammate) is widely used to poison undesirable hardwoods. It is most often applied directly to cut stems or stumps of woody plants in dry crystalline form, as a water solution, or occasionally in an oil emulsion. Ammate is also highly toxic when used as a foliage spray against brush. However, the large quantities required make cost of spray application too high for widespread use. Ammate is corrosive to ordinary metal containers. Therefore, stainless steel or protectively coated equipment is required.

Other Chemicals

Phenoxy compounds other than 2, 4-D and 2, 4, 5-T hold considerable promise for use against woody plants. Coulter (46) reports 2, 4, 5-trichlorophenoxyproprionic (2, 4, 5-TP) is more effective on some oaks than 2, 4, 5-T, and Leonard (140) believes 2-methyl-4-chlorophenoxyacetic acid (MCP) holds promise for woody plant control. 4-chlorophenoxyacetic acid and closely related compounds may also prove useful.

Arsenicals. Sodium arsenite is an effective tree killer. It has found increasing use for the dual job of killing trees and loosening bark in both this country and Canada. However, its extreme toxicity to man and animals has limited its usefulness. Swain (218) has attempted to minimize the hazard to animals by slitting the bark of trees and inserting small pieces of blotter impregnated with sodium arsenite between bark and wood.

TCA. Salts of trichloroacetic acid, popularly known as TCA, are used to control weed grasses on farms. TCA may also be useful in woody plant control as an agent to increase the activity of 2, 4-D and 2, 4, 5-T. However, foresters are not likely to find it generally useful as a grass killer because of its high cost.

Sodium Chlorate. Sodium chlorate can be used very effectively in a foliage spray against mixed brush. It is used as a soil sterilant and to some extent for killing ribes. Usefulness of sodium chlorate is limited, however, because it oxidizes readily and tends to cause fires.

The Dinitros. Dinitro-o-sec.butyl phenol (DNOSBP) and related compounds were used in earlier attempts to kill brush. They quickly kill those parts of the plant directly contacted, but sprouting generally follows.

Oils. Stove oil, the less highly refined grades of diesel, certain refinery residues, and other oils that contain a high percentage of unsaturated hydrocarbon compounds are sometimes used as herbicides, mainly for agricultural purposes. Mesquite has been effectively controlled by thoroughly covering the root-stem transition zone with diesel oil. However, oils have not been widely used as the toxic agent in other brush-control work.

Borax. Borax is occasionally used to kill undesirable plants by sterilizing the soil. It is sometimes mixed with sodium chlorate to provide a soil sterilant more toxic than borax alone and without the fire danger of sodium chlorate. Boron may also prove useful in increasing effectiveness of hormone herbicides.

New Chemicals. New improved chemicals are constantly being sought and sometimes found. 2, 2-dichloroproprionic acid, an improved grass killer now being marketed as Dalapon, is a good example.

Cost of Chemicals

Cost of chemicals ranges from a few cents to 3 or 4 dollars per pound. Cost of chemicals is not a reliable measure of cost of treatment, however, because a small amount of an expensive chemical is often just as effective as a much larger amount of a cheap chemical. Approximate price ranges per pound for some of the leading chemicals are:

Chemical	Cost per pound (dollars)
2, 4-D (acid equivalent)	1.00 - 1.50
2, 4, 5-T (acid equivalent)	2.00 - 3.00
MCP (acid equivalent)	2.00 - 3.00
Ammonium sulfamate	0.15 - 0.25
Arsenicals	0.06 - 0.10
Borax	0.02 - 0.03
Sodium chlorate	About 0.12
TCA	0.45 - 0.60

Concentration and Dosage

The two methods commonly used for regulating the amount of chemical applied are: (1) a measured amount of active herbicide is applied per acre in a stated volume of carrier, or (2) a solution of a given strength is applied to individual plants to the point of runoff, or some similar measure. Where a stated amount is applied per acre, preparing the chemical solutions presents no problem. Preparing solutions and emulsions of a specified strength is more difficult, largely because of the many ways that concentration is expressed. Those readers faced with the problem of either getting the correct concentration or converting one kind of expression of concentration to another should refer to the appendix (table 4).

Choice of Chemicals

Choice of chemical for a particular brush-control job depends largely on species present, degree of control needed, and method of application chosen. General recommendations are considered in the section that follows. Detailed recommendations for certain species are given in the appendix (table 1).

Application and Equipment

Chemicals have been applied to weed trees and brush in many different ways--to foliage, to bark, or in frills, cups, or slits through the bark. Any method that introduces enough chemical into the conducting tissue of the plant will work. Most practices currently used by foresters can be grouped into one of four broad methods:

1. Foliage applications.

2. Basal applications.

3. Cut-surface applications.

4. Soil applications (seldom used in brush-control work).

For some brush species there is a choice of methods. Red alder, for example, has been successfully controlled both by foliage sprays and basal sprays. In this case the cheapest method should obviously be selected. For some species only one method will get results.

Foliage Applications

Foliage spraying is generally recommended on susceptible species of brush not over 6 to 8 feet high. However, much taller brush may be successfully sprayed from the air or along roadsides. A high percent of kill can be obtained with susceptible species such as red alder, nonsprouting manzanita,and sagebrush. Aerial parts of many other plants such as snowbrush and chinkapin may also be killed, but the brush stand is reestablished from sprouts. Sometimes a temporary setback of brush is adequate to place established trees in a dominant position. Where a single foliage application is not successful, more than one application may prove effective. For example, McIlvain (162) was able to achieve good control over shinnery oak at moderate cost with two or three foliage applications.

Foliage spraying is very popular even though many species are not completely controlled. This is because it is the only method that lends itself readily to cheap, mass application such as spraying from airplanes or mobile power sprayers. In many cases chemical brush control will be feasible only where large areas can be successfully treated quickly and cheaply. Pearse (194), for example, said, "For the vast areas of range heavily infested with weeds or brush of one kind or another the main reliance must be placed on a low cost, rapid, and extensive method." Jankowski (122) expressed a similar view concerning brush on forest lands of the Lake States when he said, "In my opinion, to have widespread use, any brush control chemical must be adapted to aerial application."

Chemicals Used. Principal chemicals used for foliage spraying are 2, 4-D, 2, 4, 5-T, and Ammate. In addition, sodium chlorate and MCP are occasionally used. Usually either 2, 4-D or 2, 4, 5-T alone is used against stands of a single species of brush. The choice depends upon which one is most effective. If either chemical will work, 2, 4-D is normally used because it costs about half as much as 2, 4, 5-T. Mixtures of 2, 4-D and 2, 4, 5-T are often used against stands of mixed brush. Ammate is sometimes used to control brush not susceptible to either 2, 4-D or 2, 4, 5-T or in places where drift from the phenoxy compounds might damage crops.

Time of Application. Stage of growth at time of application is a critical factor in the success or failure of foliage sprays. Crafts (54) found that active root growth and downward translocation of food materials are essential for a good kill. For deciduous species these conditions are best met after the first spurt of new twig and leaf growth is complete but before a lack of soil moisture limits root

growth. Length of spraying season is governed by duration of active growth. Thus, Baisinger 5/ reports spraying of red alder and willow in northwest Oregon is effective in June, July, and August; but Crafts (57) reports good results on blue oak in California during only a brief time in early summer.

Results with foliage sprays on evergreen brush species are often poor during the period of active top growth. Crafts' (57) experience with Christmasberry (toyon) illustrates this point very well. Best results were obtained during February and March when root growth was active and products of photosynthesis were being translocated to the roots. Spray treatments failed after bud break in April because food movement was largely upward to support top and fruit growth. Even though translocation into the roots took place in late summer and fall, spray treatment failed because low soil moisture prevented root growth.

Spray Mixtures. Foliage spray mixtures always contain at least a herbicide (usually 2,4-D, 2,4,5-T, or Ammate) and a carrier. Emulsion stabilizers and wetting agents may be added. Carriers, usually water or oil, are used to provide enough bulk to extend the herbicide evenly over plant surfaces. Water is cheap, mixes well with compounds such as sodium and amine salts of 2,4-D or 2,4,5-T, and is heavy enough to penetrate into dense clumps of vegetation. Disadvantages of water are its poor spreading qualities and its inability to penetrate waxy leaf surfaces. Oil spreads well and is better able to penetrate leaf surfaces.

Water alone is often a satisfactory carrier where plants have thin and relative wax-free leaves. However, oil or an emulsion containing oil is often required on plants with thick, leathery leaves. The following experiences illustrate the point:

1. Baisinger 5/ found the use of oil on red alder and willow to be a waste of money.

2. Neuns (180) reports an oil emulsion was best on chaparral type brush on the Shasta National Forest.

5/ Baisinger, D. H. Brush spraying operations - 1951 season - on Crown Zellerbach lands. (Office report on file at Crown Zellerbach Corporation office, Portland, Ore. 4 pp.)

3. McIlvain (162) found a straight water carrier was not as effective against shinnery oak as oil or an emulsion containing oil.

Freed (82) believes the ideal volume of water carrier for 2,4-D and other phenoxy compounds is in the range of 20 to 100 gallons per acre. Yet much lower volumes are being successfully used; Hawkes (102), for example, found 8 gallons satisfactory on red alder.

When oil or oil emulsions are used, volume of carrier can often be further reduced. Thus Robbins and collaborators (205) report that 5 gallons of oil are commonly used for aerial application to brush, and Manuel (158) said 1 to 3 gallons are ordinarily used in the Lake States. Three gallons of oil in water emulsion proved adequate on ceanothus and manzanita in central Oregon.

Character of brush may influence volume of carrier needed. McIlvain (162) found 5 gallons of oil or oil emulsion per acre satisfactory for ordinary stands of shinnery oak but recommended up to 10 gallons for dense patches. Some species require more thorough wetting and higher spray volumes. For example, Baisinger 6/ found some evidence that as much as 200 gallons of oil in water emulsion may be required to kill salmonberry.

Dust. Dust has occasionally been used as a carrier for foliage applications of 2,4-D or 2,4,5-T. Drifting is a serious problem because 70 to 80 percent of commercial dust is in particle sizes ranging from 1 to 10 microns in diameter. As a result, difficulty is encountered in building up a lethal quantity on leaves. Damage to nearby crops may also be severe. Hawkes (102), for example, reports such severe drifting that a minimum buffer strip of 2 miles is needed. Such results have led the Civil Aeronautics Authority to ban application of 2,4-D dusts from airplanes.

Foliage Spraying Equipment

Main requirements of equipment for foliage application of herbicides according to Robbins and associates (205) are "(1) that it dispenses material at a uniform, controllable rate, (2) that it distributes the material uniformly over the area being treated, and (3) that it be easily calibrated to apply a predetermined dosage."

6/ Baisinger, D. H. Applied forest research - progress report for July, August and September, 1953 (copy on file at Crown Zellerbach Corporation office, Portland, Ore.)

Sprayers for foliage applications may be divided into six types: (1) aircraft sprayers, (2) mist blowers, (3) boom-type ground sprayers, (4) power sprayers with hand-operated nozzles, (5) hand sprayers, and (6) roadside sprayers. Mechanical details of common sprayers are thoroughly discussed by Akesson and Harvey (4), Page (188), and Robbins and associates (205).

Aircraft Sprayers. Aerial application of foliage sprays is fast and cheap. Either fixed-wing planes or helicopters may be used. Aerial spraying is especially adapted to large continuous areas, but patches down to about 2-1/2 acres in size can be sprayed. Obstacles (rough terrain, snags, or trees) that force the plane to deviate from its course or increase its height above the ground cause spotty results.

Helicopters give better results than fixed-wing planes in rough country or with hard-to-control brush species. The high speed of fixed-wing planes throws too much spray on one side but not enough on the other. This difficulty is eliminated with the helicopter because of both lower speed and down draft from the rotors. Furthermore, helicopters can fly over hills and across canyons at a fairly uniform height above ground. Fixed-wing planes are much more restricted in their vertical movements, but they can do the job more cheaply where gentle topography and susceptible species permit their use.

Size of spray droplet has a considerable effect on results, particularly with aerial sprayers. Manuel (158) reports that coarse droplets are largely caught by overstory vegetation, but fine foglike sprays cover everything clear to the ground. By reducing droplet size to a point where most droplets were 50 to 100 microns in diameter, Offord and Voss (186) achieved a fairly uniform defoliation of kidneywort (coyote brush) with only three-fourths gallon of oil carrier per acre. Mullison (178) concluded that it makes little difference whether one large droplet or several smaller ones are deposited on a leaf. Fisher and co-workers (79) report considerable loss from drift if droplets are too fine. For aerial application to mesquite they considered the ideal droplet size ranged from 300 to 450 microns in diameter. Even a light breeze will drift finer droplets a surprising distance (figure 1).

Pacific Northwest brush species that have been successfully sprayed from the air include red alder, manzanita, bitter cherry, ribes, sagebrush, and willow. Leonard (140) believes additional brush species will be brought under control by aerial spraying, but he says it is now evident that some woody plants are not likely to be controlled by this method.

Principal limitations of aircraft are: (1) some materials drift to nearby sensitive crops, (2) only low volumes can be applied economically, and (3) penetration into tall dense brush is difficult. Hawkes (102) reports very little drifting of the spray itself, but vapors from the isopropyl ester of 2, 4-D spread as much as one-eighth of a mile against the breeze and up to half a mile with the breeze. Robbins and associates (205) emphasize the danger of spray drifting when applied by airplane.

Maximum volume generally considered economically feasible for air application is in the range of 10 to 15 gallons per acre. When such low volumes are applied from planes, penetration into dense brush is often poor. Larson (129) reported alder was readily killed, but penetration of spray into understory vegetation was poor. At Cascade Head Experimental Forest on the Oregon coast even helicopter-applied spray penetrated dense salmonberry clumps only a foot or two in most places.

Cost of applying aerial sprays with fixed-wing planes averages $1.50 to $2 per acre. Hawkes (102) found the cost of applying 8 gallons of spray was $1.50 per acre. Paul Lauterbach, research forester, Weyerhaeuser Timber Company, in discussions with the writers, reported costs of from $2.50 to $4 for applying 5 to 8 gallons per acre on 5- and 10-acre experimental plots. Flying costs for an experimental brush spraying on the Deschutes National Forest illustrate the effect of spray volume on cost. The charge for the first 2 gallons per acre was 50 cents per gallon; each additional gallon per acre cost 25 cents.

Cost of spraying with helicopters averages about 30 to 50 percent more than for fixed-wing planes, according to Lauterbach. He reports costs of $2.70 and upward for applying 5 gallons of spray per acre in a large-scale operation. DeJarnette (65) reports costs of $3 to $4 for applying 10 gallons of spray per acre by helicopter. Costs of helicopter application increase rapidly as volume of spray per unit area is increased; the difference between costs of helicopter and fixed-wing application is therefore least with low spray volume.

Mist Blowers. Mist blowers provide a cheap, rapid method of applying foliage sprays under some circumstances. They blow out a large volume of air at high speed, which carries a relatively small amount of liquid injected into the air stream by atomizing nozzles. Offord and associates (187) found a mist blower mounted on a trailer successful for spraying roadside ribes. Cornelius and Graham were also impressed by the use of a mist blower on sagebrush. Their

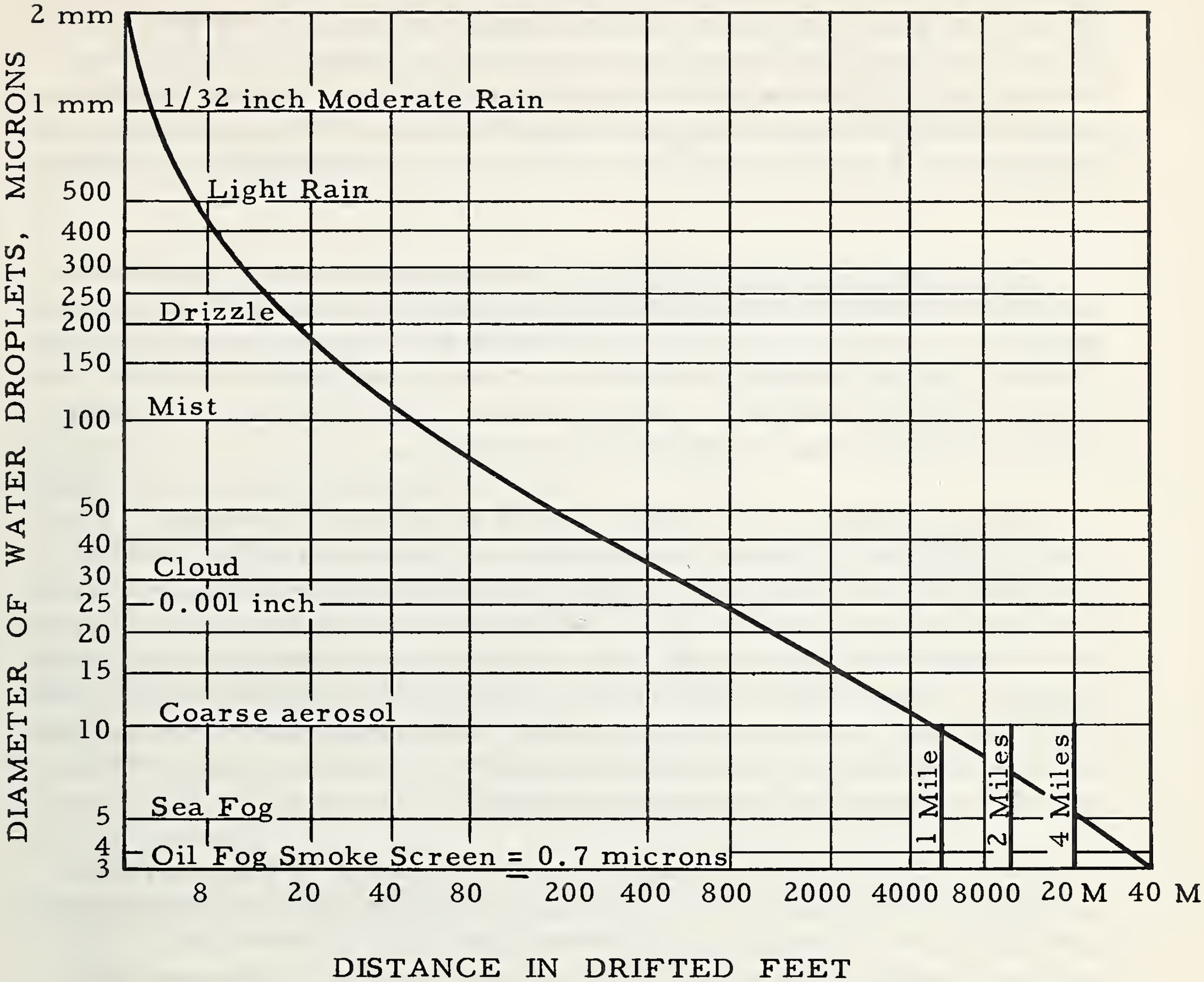

Figure 1.--Drift of various size water droplets while settling 10 feet in straight air flow of 3 miles per hour. From: Brooks, F. A., The drifting of poisonous dusts applied by airplanes and land rigs. Agricultural Engineering. 28(6): 234. June 1947. Reproduced by permission of Agricultural Engineering.

tests on sagebrush showed the mist blower covered a swath 80 feet or more wide but that optimum coverage was confined to about 60 feet.[7] Cost of operating the mist blower, which was carried in the back of a 4-wheel-drive pickup, amounted to 72 cents per acre. This figure includes labor, transportation of material, and pickup mileage on a 300-acre project. For rougher land, Cornelius and Graham suggested mounting the machine on a crawler-type tractor. Operation of a tractor-mounted sprayer would undoubtedly be more costly.

Boom-type Ground Sprayers. Boom sprayers are common for agricultural use but have not been fully adapted for use on rough, wild land. Cornelius and Graham report getting good coverage with a boom sprayer mounted on a wheel tractor, but such a machine obviously is not adapted to rough terrain. This difficulty might be surmounted by using a crawler-type tractor.

Hand Sprayers. A variety of hand sprayers is available. They range from low-pressure compressed-air sprayers with a built-in air pump to the Hi-Fog gun capable of delivering pressures up to 1,000 pounds per square inch. Hand sprayers are commonly carried on a packboard or suspended from a strap slung over the operator's shoulder. Capacities range from 3-1/5 quarts for the Hi-Fog gun to 4 or 5 gallons for low-pressure types. Hand sprayers are ordinarily used for small patches, scattered individual plants, or places that cannot be reached with power equipment.

Power Sprayers with Hand-operated Nozzles. Power sprayers equipped with multiple hoses and hand-operated nozzles are used for spraying ribes in large-scale blister rust control operations. One sprayer capable of delivering up to 20 gallons per minute can keep 10 nozzles going at one time. Hoses may be strung out as far as 3,000 feet from the sprayer. Using such equipment Offord and associates (187) found that brush typical of the Idaho white pine belt can be sprayed at the rate of about 1-1/3 acres per man-day. The Rogue River National Forest, however, reports that spraying snowbrush, chinkapin, and manzanita with such equipment was expensive; dragging hoses around in the brush was very time consuming.

7/ Cornelius, Donald R., and Graham, Charles A. Spraying equipment. (Typewritten report on file at California Forest and Range Expt. Sta. Berkeley, Calif. 3 pp. 1953.)

Roadside Spray Equipment. Roadside spray equipment is generally mounted on a truck. Nozzles are hand operated or mounted on a boom fixed to the side of the truck. A variety of pumps and tanks is used. Neuns (180), for example, reports that on the Shasta National Forest a stake body truck was used to carry the equipment. Spray solution was held in barrels, and pressure was supplied by a fire pump. Spray was applied by two men, one walking on either side of the road, with hand-controlled nozzles. Costs averaged $28 per mile (both sides) in 1950, and $25 in 1951.

Strege (216) used a slip-on fire pump unit for roadside brush spraying. Fire equipment was chosen partly to demonstrate its dual use and thus indirectly encourage more small operators to have it on hand for fire-fighting purposes. All rubber parts in such equipment must be replaced with neoprene before it is used for spraying. The cost ($28.18 per mile) probably could have been reduced if a sprayer designed for the job had been used.

The U. S. Forest Service at Missoula, Montana, designed a sprayer especially for roadside spraying. It consisted of a 300-gallon tank and a 15-gallon-per-minute, 500-pound pressure pump driven by an 8.6-horsepower gasoline engine. A 2-ton truck with a 2-speed rear axle carried the equipment. Nozzles were mounted on vertical booms fixed to each side of the truck. This equipment was operated by a driver and one helper. The Coeur d'Alene National Forest reported total cost of roadside spraying with this machine averaged $12.30 per mile.

Basal Application and Equipment

Basal sprays are applied to the lower 12 to 15 inches of a tree or bush stem. This method is used to control species not seriously damaged by foliage spraying or where selective treatment of individual plants is necessary. Sometimes it is used as a followup after foliage spraying to kill resistant plants. Year-round operations are possible because basal applications are effective at any season.

Chemicals Used. Ester forms of either 2, 4-D or 2, 4, 5-T may be used for basal spraying. However, 2, 4, 5-T is effective on more species. Martin (159), for example, found that either 2, 4-D or 2, 4, 5-T was effective on sassafras, but 2, 4, 5-T was much better on common persimmon. Similarly, Morrow (174) reports that both 2, 4-D and 2, 4, 5-T were effective on aspen, but twice as strong a solution of 2, 4-D was required. Only 2, 4, 5-T was effective on

beech. Such results led Chaiken (38) to recommend only 2, 4, 5-T, particularly where mixed brush species are involved.

Freed (82) reports that for a wide range of species 2- to 3-percent solutions of 2, 4-D or 2, 4, 5-T (acid equivalent by weight) have proved optimum. Melander (168) recognizes about 2 percent as the minimum generally effective concentration, but weaker solutions are effective on some species. Thus, Morrow (174) reports a 1/2-percent solution of 2, 4, 5-T is effective on aspen. Also Chaiken (38) reports 1-percent solutions are effective on some southern species, but he recommends a 3-percent solution for general spraying. Coulter (48, 49) points out that a good soaking with a near minimum strength solution uses less chemical and gets better results than sparing use of a concentrated solution.

Carrier. Carrier for basal sprays is almost always oil, usually diesel or stove oil. Although emulsions of oil and water are generally not recommended, Beatty (21) reports emulsions show enough promise to warrant further study.

Seasonal Effect. Basal sprays are generally effective year round. Nevertheless, some investigators report seasonal differences. Arend (15) points out that aspen treated during the dormant or early growing seasons tends to sprout while aspen treated during the main growing season does not. Suggitt (217) got poor kill during early dormancy and best results after the buds began to break. Hackett (95) found a little more chemical was needed during the winter to achieve a satisfactory kill.

Translocation. Coulter (48, 49) reports movement of herbicides apparently is largely upward during the dormant season. Beatty (21) agrees with Coulter and believes that sprouting from the root-stem transition zone is inhibited more by physical coverage of that area than by downward translocation. Another interesting fact developed by Coulter (48, 49) is that herbicides applied to the basal portion of a plant can be translocated to the growing tips without harming the middle stem area.

Application. For successful application of basal sprays the lower 12 to 15 inches of the stem should usually be well soaked and the root-stem transition zone thoroughly covered. Melander (168) believes that for small shrubs the entire plant should be sprayed with special emphasis on the ground line. For barberry plants, which reproduce from underground rhizomes, he also found a 100-percent kill was obtained by spraying not only the plant itself but also the ground for

a distance of about 4 feet out from the last shoot. Plants that do not sprout from the root-stem transition zone may not require that this area be covered. Gail M. Thomas, forester, Western Pine Association, reported in a letter to the Dow Chemical Company that ponderosa pine trees were killed by basal spraying even when a foot of snow at times prevented the herbicide from getting to the root collar.

Morrow (174) points out that results do not become apparent immediately and should not be judged until the second growing season. At the Pringle Falls Experimental Forest in central Oregon, ponderosa pine trees treated in the fall of 1953 and the spring of 1954 began dying during July of 1954 and were definitely dead by the end of the first summer.

Spraying Equipment. Freed (82) makes the following recommendations on equipment for applying basal sprays: Almost any type of equipment, ranging from a 3-gallon knapsack sprayer to more elaborate power equipment, may be used. Nozzles are the standard weed-control nozzles mounted in a U-shaped piece of pipe; diameter of the U-shaped hook should be large enough to leave an ample margin between nozzle and tree trunk when the open end of the U is passed around the tree. Day (64) reports that most basal spraying is done with hand sprayers.

Cost. Basal spraying may be cheap by some standards but costly by others. It may be cheaper to apply a basal spray to unwanted trees in a thinning operation than to chop them down. However, Chaiken (38) points out that for larger sized trees basal spraying costs are high because a large amount of chemical is required. He reports that cost of basal spray chemicals alone was about 5 cents for a 6-inch tree and 21 cents for a 15-inch tree. Arend and Stephenson (17) agree with Chaiken and state that trees larger than 4 to 6 inches in diameter require too much chemical for treatment by the basal spray method.

Cut-surface Applications and Equipment

Chemicals may be introduced directly into trees through various types of cuts in the stem such as notches or frills on freshly cut stumps. Much less chemical is required for this type of treatment than for basal application. Cut-surface methods have been used for killing undesirable hardwood trees and ribes, and for preventing stumps from sprouting. Similar methods may also be useful for thinning young forest stands. Generally, cut-surface methods are more efficient for trees 4 inches or larger and basal

spraying or felling for smaller trees. Chemical treatments are often preferred over girdling or felling because they reduce hardwood sprouting, lessen amount of axe work, and may reduce beetle activity with such species as ponderosa pine.

Chemicals Used. The most common chemicals used for cut-surface methods are 2, 4, 5-T, 2, 4-D, and Ammate. Arsenic may also be used. Robbins and associates (205) and Leonard and Carlson (146) report amine formulations of the phenoxy compounds are superior to other forms. Peevy (198) reports good results from both amine and ester formulations. Arend (14), however, prefers the ester forms. Either water or oil may serve as the carrier for the phenoxy compounds. Water is generally used in the South, but Arend (14) has found oil to be superior in the Lake States for the following reasons: (1) A better kill is obtained, (2) axe cuts may be shallower, and (3) the solution does not freeze in winter. Concentrations of 8 pounds a.h.g. (acid per hundred gallons) of 2, 4, 5-T in water emulsions are normally used, but 4 pounds a.h.g. have proved adequate with an oil carrier. Leonard (136, 143) has obtained good results with undiluted amine 2, 4-D.

Ammate may be used in dry crystalline form or as a water solution. When solutions are used, 4 pounds of Ammate crystals per gallon is the preferred strength, but 2 pounds is often recommended. One of the difficulties with Ammate solutions is that they corrode metal.

Techniques and Equipment. Various methods and tools have been used for cut-surface application of chemicals. Most common is the frill girdle made with an axe and filled with chemical from a can or knapsack sprayer. The frills are simply overlapping axe cuts about one-half inch deep all around the tree. Backpack cans, equipped with a hose and arranged for gravity feed, or a knapsack sprayer with low pressure can be used for applying the chemical to the frill. Chaiken (36) points out that the frill must be thoroughly filled with chemical. Arend (14) has found that less care is required if oil is used as the carrier. Four men, three chopping and one pouring, is an efficient crew for frilling. Difficulty in telling which trees have been poisoned is eliminated if a dye is added to the chemical solution.

Chemical frill girdling may also be accomplished by means of the Cornell tool, which was developed by Cope and Spaeth (44) for use with sodium arsenite. It is currently being used with the phenoxy compounds in either water or oil or with Ammate in water. It is a barlike tool with a sharp edge and a hollow handle. The frill is made by jabbing with the sharp edge. A little chemical from the handle is

released into this frill with each jab. Arend (14) reports the Cornell tool is cheaper to use than an axe.

Leonard (136, 143) has killed blue oak with a modification of the frilling technique that involved spacing hatchet cuts 6 inches apart center to center. Digger pine was killed with cuts spaced 8 inches apart, but a continuous frill was required for canyon live oak. Two cc's (cubic centimeters) of undiluted amine 2, 4-D (4 pounds acid equivalent per gallon) were squirted into each cut. A preliminary trial at Pringle Falls Experimental Forest indicates that pole-sized ponderosa pine trees can be killed by covering about half of the bole circumference with cuts. Four cc's (one squirt with an oil can) of undiluted amine 2, 4-D (4 pounds acid equivalent per gallon) per cut was used. Results of trials with lesser amounts of chemical and more widely spaced cuts are not yet available. This technique has real promise for greatly reducing thinning costs.

Ammate crystals are sometimes used in notches or cups cut near the base of the tree. Arend (14) reports Ammate used in this way is more effective than as a solution poured into a frill. Cost of notch application, however, is about twice that of the frill method. Herman (106) found Ammate in notches was a very effective way of poisoning cull ponderosa pine. He also reports that Ips beetles did not build up in the poisoned trees to the point where reserved trees were attacked.

Stumps of most undesirable species can be prevented from sprouting, but it is generally cheaper to poison the standing tree unless it has a definite value. Stump poisoning is accomplished by drenching the tops and sides, including the root-stem transition zone, with 1- or 2-percent solutions of 2, 4-D or 2, 4, 5-T in oil. 2, 4, 5-T is often considered the more effective even on plants sensitive to 2, 4-D. Another method sometimes used on small stumps is to place Ammate crystals in a V-shaped notch in the top.

A unique method of using sodium arsenite is reported by Swain (218). He developed tools for inserting small pieces of blotting paper impregnated with sodium arsenite under a tree's bark. By this method the chemical is effectively applied to the tree but is kept away from animals. The method worked on pine all year around in New England, but bark on hardwoods was too tough except during the peeling season. Tests at Pringle Falls Experimental Forest show that ponderosa pine is difficult to treat by this method because of thick, brittle bark, but lodgepole pine is easily treated. Not all trees of either species over 3 or 4 inches d.b.h. were killed. Leonard's cut-surface method was faster, safer, and surer.

Cut-surface methods are extensively used in the South and East, but experience in the Northwest has been too limited to furnish reliable cost data.

Soil Applications

Foresters occasionally apply herbicides directly to the soil for absorption by plant roots. Examples are application of sodium chlorate to soil around cutoff blackberry plants, or Ammate and other chemicals to soil around ribes plants.

Herbicides unintentionally applied to soil during foliage or basal spraying operations may, in some cases, cause concern. Where summers are warm and moist, disintegration of 2, 4-D is rapid, but under dry conditions it has remained in the soil in lethal quantities for as long as 6 to 9 months. Even small quantities in the soil can have considerable effect. Roots are 10 to 100 times as sensitive to 2, 4-D as shoots. Some seeds are also extremely sensitive. Such effects may aid in destruction of unwanted plants like mesquite and ribes or hinder and delay establishment of desirable tree species.

MECHANICAL METHODS

Mechanical brush control is not a new method to foresters. Typical practices include skidding logs through brushy patches and use of bulldozers and root planes to eliminate brush and make room for planted or natural seedlings. Various mechanical devices have been used to eradicate ribes and to eliminate brush on rangeland.

Machines and Techniques

Brush Beaters

Brush-beating machines consist of a set of weighted chains fastened to a horizontal revolving shaft. The chains shred the foliage and woody portions of brush in a manner similar to a hammer mill. Beaters are available in sizes which will effectively clear tall brush and small trees. They are considered good only on brittle tall species, but can also handle tough low vegetation. Beaters have been used to shred tops of sprouting species preparatory to spraying the resulting sprouts with chemicals. Brush beaters are well adapted for use on rough and rocky areas. They cause a minimum of erosion because they leave a protective mulch on the ground.

Bulldozers

Bulldozers uproot and remove large brush and small trees. They operate on slopes up to 40 percent, but soil disturbance increases with slope. On steep ground, it is recommended that the blade be held about a foot above the ground to minimize soil disturbance. Under these conditions the dozer is impractical on low brush because small stems usually bend without being uprooted. On gentle slopes with stable soil the blade is usually operated at ground level or slightly below. The ground is left very rough, but live brush and small trees are cut off at or below the soil surface. Humus and surface soil are mixed considerably, many surface roots are pulled out, and future sprouting is reduced. Dozers or similar machines have been widely used in brush control in spite of high operating costs.

Cabling

Cabling consists of dragging a heavy cable or chain, 300 to 400 feet long, between two tractors moving parallel to one another. One trip pulls over much of the taller brush and most trees. A second trip from the opposite direction tears many partially uprooted trees and bushes completely out of the soil. Cabling does not seriously dig or cut into the soil nor does it provide a high degree of permanent brush control. Many small stems escape altogether and a large number of partially uprooted bushes resprout. Speed of operation and low cost make cabling attractive where the brush control obtained meets management objectives.

Cutters

Cutters are machines with from 4 to 12 blades each 4 to 10 feet long, mounted on a large steel cylinder. The cylinder is mounted on two wheels and pulled behind a tractor. Blade height is adjustable. As the machine is pulled forward, the brush is mashed and cut into short pieces. Cutters are made in sizes varying from 1,000 to 28,000 pounds. A 28,000-pound cutter used extensively in clearing pipeline rights-of-way is capable of clearing brush and trees up to 8 inches in diameter. Several commercial cutters are weighted with water so that the weight of the machine may be adjusted. The following benefits are claimed for cutters: (1) killing of undesirable vegetation, (2) light cultivation of the ground, and (3) soil protection, as the "chewed up" brush leaves a protective litter on the surface. A cutter's usefulness is somewhat limited

for the following reasons: (1) not sufficiently effective on sprouting species, (2) rocky soils quickly dull blades, and (3) does not kill seedlings, small plants, and low-lying branches.

Mowers

Heavy-duty, power take-off mowers are reasonably effective on small-stemmed, flexible shrubs. They are normally limited in use to brush which is not over 3 inches in diameter. However, extremely hard tough brush may limit the upper size to 1-1/2 inches in diameter. Mowers are not effective on strongly sprouting species unless the operation is repeated or is followed by chemical treatment to control sprouts.

Root Planes or Root Plows

This implement is a heavy, rugged sweep mounted on the back of large crawler-type tractor. It is drawn beneath the soil surface and severs underground stems and roots. Soil is disturbed considerably since some machines cut swaths 8 to 10 feet wide of 6 to 8 inches deep. They should not be used where erosion, either wind or water, is a threat. Their use is further restricted to relatively rock-free soils and to land of gentle topography. Root planes and root plows have been used effectively for grubbing mesquite, big sagebrush, and California scrub oak.

Plows

Plows are most effective on brush less than 4 feet tall. Certain brittle species such as big sagebrush can be handled up to 6 feet. Good mechanical control has been obtained on gentle slopes with few surface rocks. Crown area has been reduced as much as 99 percent on some species of sagebrush. Equipment breakage is high with one-way and offset disk plows. This limitation has been partly overcome in the new brushland plow developed primarily for killing sagebrush and other shrubby plants on rough rangeland. The brushland plow incorporates some principles of the Australian stump-jump plow and works efficiently on moderately rocky soils. Pairs of disks, independently sprung, provide flexibility and low breakage. The disks scoop as they roll and tend to cut brush roots instead of rolling over them. Although developed primarily for sagebrush removal, the brushland plow seems well adapted for solution of certain forestry brush problems.

Railing

Railing is the technique of uprooting, breaking off, or mashing down brush by dragging a railroad rail over it. Dragging of large stumps and anchor chains has also effectively removed undesirable vegetation. Railing is generally limited to moderately low, non-sprouting shrubs that are stiff or brittle. It is of little value for species which sprout or which have flexible tops. The method is inexpensive and has been widely used. Lyman and Sykes (156) describe an excellent example of railing in Hawaii.

Saws

At least 10 different kinds of saws are being produced and used. Some are mounted on the front of wheel tractors and are driven from power take-off shafts or belt pulleys. These saws can generally be used with the tractor in motion. Other types feature a saw blade powered by a small motor mounted on a 2-wheel frame that can be moved by hand. A lightweight brush saw is available which consists of a cutting head mounted at the base of a 4-foot shaft and powered by a 1- to 2-horsepower gasoline engine. Portable chain saws have also been used to some extent for clearing large, woody stems and trees. All of these types have given excellent results. The two main limitations are high cost and tendency of saw blades to bind in the cut when sawing large trees.

Other Equipment

In addition to the above-described machines, mobile shears, grubbers, shredders, flame throwers, and tillers are sometimes used.

Costs

Cost of mechanical brush control varies considerably. Some brushfields have been effectively cleared for as little as $2 per acre while others have cost $60 or more. Mechanical methods are generally more expensive than other methods of brush control. More than half of the available references show higher costs for mechanical control than for prescribed burning and chemical treatments. However, with gentle topography, moderate-sized vegetation, and few rocks, costs of mechanical methods are sometimes reasonable. The following examples illustrate this point:

1. Tannehill (219) reports average costs of only $6.72 per acre for clearing dense brush consisting of thousands of hardwood and brush stems per acre with an HD-7 tractor. Some stems were as large as 6 inches in diameter.

2. Love and Jones (155) report clearing extensive brush fields in California for $15 per acre.

3. McQuilkin (165) reports a D-7 tractor was able to cut alternate furrows 9.3 feet wide through a California scrub oak stand for $11.25 per acre, and Fixmer [8/] reported clearing alternate 10-foot-wide swaths for $5.88 per acre with one-direction treatment and $12.38 for two-direction treatment.

At the other end of the scale was an operation on the Stanislaus National Forest where costs of $58.55 per acre were reported for tractor brush removal in 1948. Costs were reduced to $37.38 the next year after the machine operator gained experience.

CONTROL BY PRESCRIBED BURNING

Prescribed burning is used on forest and range lands in many sections of the United States to control undesirable vegetation, prepare planting sites, reduce fire hazards, improve forage for livestock and game, and to control certain tree diseases. It has been accepted generally as a desirable forest management practice in the Coastal Plain of the South and in the New Jersey oak-pine region. Fire has been used extensively in the Northern Rocky Mountain white pine type. In California, it is used as a step in the restoration of brushland ranges. Ranchers burned approximately 400,000 acres of brushlands in California during the period from 1945 to 1951; 102,000 acres were burned during 1950 alone.

Fire may serve many useful purposes if used with skill and caution. However, expected benefits should be weighed against possible losses such as increased erosion, unintentional burning of valuable young growth, or altering unfavorably the composition of the vegetative mantle. Though broadcast burning of slash has been widely used in the Douglas-fir region of the Pacific Northwest for fire-hazard

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8/ Fixmer, F. N. Experiment in mechanical elimination of scrub oak presented at the Wisconsin-Upper Michigan Section, Society of American Foresters. Sept. 15-16, 1950.

abatement, it may prove to be useful as well in reclaiming brush fields for forest production on more stable soils.

Burning Techniques

Research on fire behavior and fire use provided several new techniques which make fire safer and more effective for brush removal. Ignition techniques include center firing, strip firing, edge firing, and combinations of these. Techniques in fuel manipulation include treatment of brush before burning with chemicals or mechanical equipment to lower its moisture content.

Center Firing

Fires are started first in the center of the area and allowed to spread toward the edges. Then when a large volume of heat has been generated, fires are started along the outer edges. Indraft causes smoke, heat, and sparks to be drawn to the center fire. This permits men to work close to the edges of the area and reduces likelihood of spot fires outside the area. Center firing should be used only on slopes up to about 20 percent when the atmosphere is calm.

Strip Firing

Strip firing is adapted to moderate and steep slopes. It can also be used on level ground or gentle slopes when the wind will cause fire to run in one direction.

On steep terrain, fires are first started along the extreme upper edge. A second strip is started a short distance down the slope as soon as the upper edge has burned out. This process is repeated until the entire area is burned over. Strip firing can be used on slopes too steep for center firing and is widely used for slash burning in the Pacific Northwest.

On level ground or gentle slopes parallel lines of fire are set progressively across the area beginning on the leeward side. On the first strip, fire burns toward a prepared fire break, but on succeeding strips it burns toward the previously burned area.

Edge Firing

Edge firing is simpler than either center or strip firing. Fires are started along control lines at the outer edge of an area and

allowed to burn into the center. The method is usually applicable only on small areas or as an auxiliary to strip or center firing.

Prescribed Burning Costs

Fire has been widely used for brush control because other methods are often too costly for general use on wild lands. Indiscriminate use of fire, however, can easily cause more damage than good. Therefore, careful planning and balancing of preparation costs against possible losses from escape are essential. When adequate safeguards are used, fire often turns out to be a fairly expensive method. Without safeguards, costs can be out of reason.

Many examples of low-cost burns are found in the literature; many for less than $1 per acre, some for only a few cents per acre. Sampson (209) reports broadcast burning of California rangeland under State supervision cost the owner from 25 to 85 cents per acre in 1949. State supervision costs were an additional 27 to 40 cents. Chaiken (37) reports large-scale burns on national forests of southeastern United States have been made for 10 to 15 cents per acre. However, the conditions and costs cited are not even roughly comparable with conditions and probable costs in the Pacific Northwest.

In the Douglas-fir region, cost of burning for brush control is probably comparable to cost of broadcast burning for slash disposal. Leslie Colvill, Division of Fire Control, Region 6, U. S. Forest Service, tells us that average cost of broadcast slash burning was $30 to $35 an acre in 1954. A large share of the cost was for men and equipment on standby during actual burning and for mopup when burning was complete. He emphasized that without these precautions damages from and suppression of escaped fires would greatly increase total slash-burning costs.

BIOLOGICAL CONTROL

Control of brush through heavy browsing or by introducing specific insects or aggressive forest trees offers possibilities.

Use of insects to control undesirable vegetation has received considerable attention in all parts of the world. More than 600 species have been imported into continental United States for plant control during the past 60 years. Approximately 100 of these have been used for various agricultural and range management purposes. Control of common St. Johnswort (Klamathweed) by a species of *Chrysolina* is one of the most notable examples in the United States. Other

outstanding examples reported by Robbins and collaborators (205) include control of pricklypear in Australia by Cactoblastis cactorum and control of a thorny shrub in the Hawaiian Islands.

Successful use of insects to control undesirable vegetation has been obtained only on exotic weed species. Long-established balances have developed between most native plants and native parasites that hinder buildup of large insect populations.9/ On forest lands, most problem brush species are native, and it appears unlikely that insects can be successfully employed for brush control.

Occasionally, however, native species are killed on rather extensive areas by parasitic insects. Snowbrush is sometimes defoliated by Nymphalis californica in eastern Oregon. Sagebrush has been killed on large areas by heavy infestations of Agroga websteri in northern Nevada, and shadscale saltbush has been killed over extensive areas in southern Idaho by a new species of the genus Eumysia. Insect infestations have also killed broom snakeweed and loco.

Control of brush by browsing animals has been widely used in agriculture and range management. Cattle, sheep, and goats effectively eliminate sprouts and seedlings where the area can be fenced to confine the animals. Goats show a preference for sprout growth and weeds, and have successfully eliminated or weakened young growth up to 5 or 6 feet in height by girdling or defoliation. Use of goats offers an economical and practical method of controlling gorse seedlings and regrowth following controlled burns. Close browsing by deer in localities of heavy animal population has also been effective in eliminating sprouting brush from burns of 4 to 6 acres in size.

Successful use of browsing animals to control undesirable vegetation on potential timber-producing sites seems unlikely. Brush areas, for example, must be fenced in order to confine animals to small parcels of land. Moreover, animal browsing may be selective and fail to control the offending brush species. Trampling by animals may also destroy tree seedlings and compact the soil.

9/ Parker, Kenneth W. Control of noxious plants and management of livestock to prevent losses from poisonous species. Southwestern Forest and Range Expt. Sta. 7 pp. No date. (Unpublished manuscript, copy on file Southwestern Forest and Range Expt. Sta., Tucson, Arizona.)

Use of conifer species which offer severe competition to intolerant weed species is another example of biological control. Plantations of Port-Orford-cedar appear promising for control of gorse, an intolerant species. In one experiment, 80 percent of the planted cedar survived intense competition of gorse. It is expected that the cedar will eventually create sufficient shade to eliminate gorse from the planted area.

Control of undesirable vegetation by disease organisms may also be a possible method of biological control, but no reports were found on the practical application of this method.

COMBINATION METHODS

Two or more methods are often combined in order to obtain more efficient brush control. To illustrate: It has been shown with some species that fire and some mechanical practices actually stimulate sprouting and that fire may induce germination of seeds stored in the duff. It has also been shown that chemical treatment often requires two or more applications to kill large brush and trees but can successfully eliminate young brush sprouts and seedlings in one application. Under these circumstances burning, or one of the less costly mechanical methods, can be used first to reduce brush size and can be followed by a single spraying to give a more effective kill at less cost.

Chemical and Fire Combination

Standing green brush can be sprayed with chemicals to deaden foliage and twigs and make them more inflammable. General-contact weed killers have reduced moisture content of green foliage and twigs to about 20 or 30 percent of their original amount in a 1- or 2-week period. Fire can then be effectively used to obtain a clean burn.

Chemical and fire combinations have been used for many years, and several successful brush-control projects vouch for their effectiveness. Sodium chlorate was applied to standing green brush as early as 1928. Burning, applied 2 weeks after chemical application, was highly successful. This combination of chemical and fire methods is being used successfully in the Northern Rocky Mountain region preparatory to planting trees.

Proper timing of chemical application and burning is of utmost importance. As an example of poor timing, DeJarnette and

Augenstein (66) report a chemical-fire treatment on the Nezperce National Forest that resulted in heavy sprouting after the burn. The fire had apparently been applied too soon after spraying, and the chemical, usually slow in translocation, had not had time to kill the roots. Maximum control might be effected if spraying were done early in the season and firing delayed until fall.

Experience on the Nezperce National Forest indicates that it might be better to burn first and then spray regrowth and seedlings. When chemicals are applied to new seedlings and sprout growth, a high degree of kill usually results. Many California ranchers are using this technique.

Mechanical and Fire Combinations

Reduction of moisture content to make brush more inflammable and elimination of debris left by machines are principal objectives of the mechanical-fire combination. Results of a California State Division of Forestry experiment illustrate this method. Where brush was burned standing without mechanical treatment, about 10 to 20 percent of the larger stems were consumed by fire. Where brush had been broken down and dried for 10 days, 60 to 80 percent were consumed. Eighty-five percent of the stems were consumed where brush had dried for about 4 months.

The mechanical-fire method also extends the period during which brush can be burned. Grah and Arnold (93), for example, report that with the "area ignition" technique, mashed down brush can be burned during spring or winter when standing brush would not ordinarily burn. This technique can be most effectively used where the brush is mashed down and allowed to dry out in strips. Dry strips are then ignited simultaneously. Ordinarily fire buildup is rapid and moisture content of green brush on undisturbed strips is lowered so that all of the brush burns rapidly. Except in very sparse stands of brush, "area ignition" has been successfully used even during periods of high humidity. In California, trials were made of removing one-half, one-third, and one-quarter of the brush by mashing it down in strips. Costs per acre were $5.46, $2, and $1.32, respectively.

Prescribed burning followed by mechanical treatment has received more limited use. Fire often leaves unburned debris in the form of partially burned clumps and stems, and completely unburned patches of varying size. Considerable regrowth and seedling germination may follow the burn. Machinery may be used to remove this new vegetation.

Mechanical and Chemical Combination

Brush is first severed, mashed, or uprooted mechanically and then treated with chemicals to kill sprouts and roots. This combination has been used successfully.[10] The purpose of the initial mechanical treatment is to reduce brush size. Sprouts can often be treated by chemicals more effectively and cheaply than larger vegetation. As an example, Elwell (74) reports application of chemicals to oak brush sprouts produced a much more effective control than application to mature plants.

Chemical application followed by machinery to mash and to uproot brush is a combination used when dead, standing vegetation is objectionable.

CHOOSING A METHOD

Each method of brush control has some weaknesses and some advantages. Methods or combinations of methods are needed to meet different situations. On one large area, for example, killing brush with chemicals may increase the fire hazard beyond the margin of safety. In contrast, more flash fuel to permit good burning may be needed on another area. On at least one clear-cut area on the Siuslaw National Forest chemical brush spraying was used to get enough flash fuel to permit a clean slash burn. Obviously generalized recommendations on choice of brush-control methods should be accepted with reservations--the generalities will not fit every case.

Recent advances have focused attention on chemical methods of brush control. The main advantages of chemical methods are:

1. Chemicals will sometimes kill or seriously damage the unwanted brush with only negligible harm to desirable conifers.

2. Sprouting may be greatly reduced or eliminated.

3. Chemical control is often the cheapest way of doing an effective job.

10/ Sanderson, J. E. Roads and trails, investigations, brush removal U. S. Forest Service, Region 1. Circular E-3350, Feb. 11, 1949.

All three advantages are illustrated on a Siuslaw National Forest project where planted Sitka spruce and Douglas-fir were released from overtopping red alder by airplane spraying. Even though sufficient 2,4-D was applied to effectively control the alder, conifers were only slightly damaged. Some alders sprouted weakly, but many were killed completely. At $5.15 per acre, cost of chemical treatment was far below other methods.

Principal limitations of chemical methods are:

1. Not all undesirable brush species are killed or damaged by small doses of a cheap chemical.

2. Dead vegetation may increase the fire hazard or hinder planting or seeding operations.

Mechanical brush control has certain advantages over fire or chemicals. Every machine will not provide all of the following advantages, but some of them may be expected when the right equipment is used.

1. A favorable seedbed is prepared by exposing mineral soil.

2. Brush may be removed or broken down, permitting ready access for planting or other activities.

3. Plant residues may be left as a surface mulch to protect soil and conserve moisture.

Principal limitations of mechanical brush control are:

1. Unsuitable for ground that is steep, rough, or rocky.

2. Erosion may be accelerated.

3. Several mechanical devices are not effective against sprouting species.

4. Costs are high.

Main advantages of fire as a brush-control method are:

1. May be cheap.

2. Cleans up the ground.

3. Reduces fire hazard.

Main limitations of fire are:

1. Dangerous to use and adequate precautions may be costly.
2. Requires a high degree of skill to use safely and effectively.
3. Results difficult to predict.
4. Effective only on nonsprouting species.
5. Stimulates germination of seeds of many undesirable brush species.
6. May impair soil productivity.
7. May impair hydrological functions of the soil.

RESEARCH NEEDED

More research aimed at improving methods for controlling brush on forest lands is needed. New developments in undesirable plant control in agriculture and other industries should be watched carefully for possible application on forest lands. This is particularly true of chemical methods. In addition, researchers should focus attention on those important species of forest brush that cannot now be satisfactorily controlled. Chances for developing successful methods are bright because the whole art of controlling undesirable plants is advancing rapidly. Attention should also be given to methods for reestablishing forests following brush control. Final success of any brush-control effort on forest land must be judged by the stand of trees established on that land.

APPENDIX

Table 1.--Chemical treatments for some Pacific Northwest brush species 1/

Species	Sprouter 2/	Herbicide 3/	Diluent 4/	Concentration or rate 5/	Kind of application 6/	Degree of control 7/	Authority 8/
Alder, red (Alnus rubra)	Yes	E.2,4-D	8 gal.water	2 ppa	FS	I	(102)
		Ammate crystals	None	-	CSC	I	A.E. Thompson, Snoqualmie N.F.
		Mixed E.2,4-D & E.2,4,5-T	DO	20 ahg	CSS	I	A. W. Smelser, Mt. Hood N.F.

1/ This list of troublesome brush species was compiled from information furnished by the 19 national forests in Oregon and Washington and by field stations of the Pacific Northwest Forest & Range Expt. Station.

2/ Sprouting habits of the species following cutting and fire.

3/ Herbicides - A (amine salt), E (ester), Na (sodium salt).

4/ Diluent - DO (diesel oil), K (kerosene).

5/ Concentration - ppm (parts per million), ahg (lbs. acid per 100 gallons carrier), % (percent acid by weight).
Dosage - ppa (pounds per acre).

6/ FS (foliage spray), BS (basal spray), CS (cut surface), CSC (cut surface cups), CSS (cut surface stumps), S (soil), DS (dormant spray).

7/ I - (Hypersensitive) - Any species or variety of a plant killed by one application of a given chemical.
II - (Sensitive) - Any species or variety of a plant injured by a given chemical and killed by repeated application. Probably most woody plants sensitive to hormone-type chemicals will fall in this class.
III - (Semi-tolerant) - Any species or variety of a plant affected by a given chemical, but not killed by repeated application. This group includes those plants that are merely defoliated by hormone spray.
IV - (Tolerant) - Any species or variety of a plant showing negligible effect from an application of a given chemical.
Fractions such as 95/90 - upper part of fraction represents percent of tops killed, and lower part represents percent of roots killed.

8/ Authority for treatment used and results obtained. Numbers refer to bibliography.

Table 1.--Chemical treatments for some Pacific Northwest brush species[1/]--continued

Species	Sprouter [2/]	Herbicide [3/]	Diluent [4/]	Concentration or rate [5/]	Kind of application [6/]	Degree of control [7/]	Authority [8/]
Ash, Oregon (Fraxinus latifolia)	Yes	2,4-D, 2,4,5-T or MCP	Water	3 ahg	FS to wet	I on plants under 15 ft. tall	(123)
Azalea, western (Azalea occidentalis)	Yes	E.2,4-D + 2,4,5-T (1:1 ratio)	Water 150 gal./A	3.28 ahg	FS	I & II	G. A. James, Port-Orford Cedar Experimental Forest.
Beargrass, common (Xerophyllum tenax)	Yes	Sodium chlorate	Water	2 lbs./gal.	Drenching spray	I & II	H. R. Offord, U. S. Forest Service, San Francisco.
		Ammate	Water	2 lbs./gal.	Drenching spray	I & II	
Blackberry, 3 species as follows:							
Himalaya (Rubus procerus)	Yes	E.2,4,5-T	Water	2 to 3 ahg	FS	II	(232)
		Sodium chlorate	None	5 lbs./sq. rod	S	II	
Evergreen (Rubus laciniatus) and		Sodium chlorate	Water	5 lbs./sq.rod 1 lb./gal.	FS	I	
Trailing (Rubus vitifolius)		Ammate	Water	6 lbs./sq.rod 3 lbs./gal.	FS	I	

Blueblossom (Ceanothus thyrsiflorus)	No	E.2,4,5-T	DO	20 ahg 2 ppa	FS	100/100	J.R. Thienes, Ext. Agent, Coos County, Oregon.
		E.2,4-D & E.2,4,5-T	Water	4 ppa	FS	I & II	
Blueberry, box (Vaccinium ovatum)	Yes	E.2,4-D	Water	2,000 ppm	FS	II	(10)
Bracken (Pteridium aquilinum)	Yes	Sodium chloride	Water	1 lb.in 1-1/2 qts. 75 gal./A	FS	II	(205)
		Sodium chloride	Water	15-20 gal./A	CS w/scythe applicator	II	
		E.2,4,5-T		2 to 4 ppa	FS	II	
Broom, Scotch (Cytisus scoparius)	Yes	Mixed E.2,4-D & 2,4,5-T	Water	4,800 ppm	FS	I & II	D.H.Baisinger, Crown Zellerbach, Portland.
		E.2,4-D	Water	2 ahg	FS	100/100	(171)
		E.2,4,5-T	Water	5 ahg	FS	100/100	(142)
		E.2,4-D	Water	10 ahg	FS	100/100	
		E.2,4-D	75% water 25% DO	5 ahg	FS	100/100	(148)
		E.2,4-D or E.2,4,5-T	DO	16 ahg	BS	100/100	(149)
Californialaurel (Umbellularia californica)	Yes	E.2,4,5-T	DO	16 ahg	BS	100/100	(149)
		Sprouts appear to be sensitive to both 2,4-D and 2,4,5-T					

See footnotes on first page of table.

Table 1.--Chemical treatments for some Pacific Northwest brush species[1]--continued

Species	Sprouter [2]	Herbicide [3]	Diluent [4]	Concentration or rate [5]	Kind of application [6]	Degree of control [7]	Authority [8]
Canada thistle (Cirsium arvense)	Yes	Sodium chlorate	Water	1 lb./sq. rod	FS spring & fall	II	(205)
		2,4-D	Water	1/2 to 1 ppa	FS	II	
Cascara, buckthorn (Rhamnus purshiana)	Yes	Mixed E.2,4-D & 2,4,5-T	Water	1,600 - 2,400 ppm	FS	I & II	D.H.Baisinger, Crown Zellerbach, Portland.
Ceanothus, squawcarpet (Ceanothus prostratus)	Yes	Low volatile E.2,4-D & 2,4,5-T	Water	2,000 ppm	FS	II or III	H. R. Offord, U. S. Forest Service, San Francisco.
Ceanothus, mountain whitethorn (Ceanothus cordulatus)	Yes	Na.) A.)2,4-D E.)	Water	1-2 ppa	FS	95/90	(183)
Cherry, bitter (Prunus emarginata)	Yes	Ammate crystals	None	None	CSC	I on trees 6 inches or less in dia.	A.E.Thompson, Snoqualmie N. F.
		2,4-D	Water 150-240 gal./A	1-1/2 qts. concentrate/A	FS	I & II	
Chinkapin (Castanopsis species)	Yes	E.2,4-D & 2,4,5-T mixed	Water	Up to 24 lbs/A	FS	II or III	V. W. Dahlin, Rogue River N. F.

Chokecherry, common (Prunus virginiana)	Yes	Mixed E.2,4-D & 2,4,5-T	Water	500-1,000 ppm each chemical 2.2 to 6.7 lbs./A	FS	I & II	(223)
		Mixed E.2,4-D & 2,4,5-T	DO	8% 22 ppa	BS first treatment	30/0	
		Mixed E.2,4-D & 2,4,5-T	DO	8% 26.3 ppa	BS re-treatment	100/100	
		E.2,4,5-T	DO	8% 20.3 ppa	BS first treatment	15/0	
		E.2,4,5-T	DO	8% 29.9 ppa	BS re-treatment	100/100	
		A.2,4-D	Water	2,000 ppm 6.7 ppa	FS first treatment	45/7	(224)
		A.2,4-D	Water	2,000 ppm 3.2 ppa	FS re-treatment	87/80	
		E.2,4-D	Water	4,000 ppm 9.7 ppa	FS first treatment	90/72	
		E.2,4-D	Water	2,000 ppm 2.1 ppa	FS re-treatment	97/95	
		E.2,4-D & E.2,4,5-T mixed	Water	2,000 ppm 6.1 ppa	FS first treatment	97/62	
		E.2,4-D & E.2,4,5-T mixed	Water	2,000 ppm 0.7 ppa	FS re-treatment	100/99	

See footnotes on first page of table.

Table 1.--Chemical treatments for some Pacific Northwest brush species[1]--continued

Species	Sprouter [2]	Herbicide [3]	Diluent [4]	Concentration or rate [5]	Kind of application [6]	Degree of control [7]	Authority [8]
Cottonwood, black (Populus trichocarpa)	Yes	Ammate crystals	None	None stated	CSC	I on trees 6 inches or less in dia.	A.E. Thompson, Snoqualmie N. F.
Currant, stink (Ribes bracteosum)	No	2,4-D	Water	0.42 ahg	FS	I	(187)
		2,4,5-T	Water	0.83 ahg	FS	I	
		2,4,5-T	Oil or water	16.7 ahg	FS	I	
		2,4,5-T	Oil or water	16.7 ahg	CSS	I	
		2,4,5-T	Oil	41.7 ahg	BS	I	
Currant, redflowering (Ribes sanguineum)	No	2,4,5-T	Water	2.1 ahg	FS	I	(187)
		2,4,5-T	Oil or water	16.7 ahg	FS	I	
		2,4,5-T	Oil or water	16.7 ahg	CSS	I	
		2,4,5-T	Oil	41.7 ahg	BS	I	
Deerbrush (Ceanothus integerrimus)	Yes	E.) A.)2,4-D Na.)	Water	1-2 ppa	FS	98/95	(184)
Dogwood, Pacific (Cornus nuttalli)	Yes	Mixed E.2,4-D & 2,4,5-T	Water	20 ahg	CSS	I	A. W. Smelser, Mt. Hood N.F.

Elder, Pacific red (Sambucus callicarpa)	Yes	Mixed E.2,4-D & 2,4,5-T	Water	2,400 ppm	FS	I & II	D.H.Baisinger, Crown Zellerbach, Portland.
		Sprouts vigorously following 2,4-D foliage spray					(102)
Elder, blueberry (Sambucus glauca)	Yes	Na. 2,4-D	Water 10 gal./ sq. rod	1,200 ppm	FS	II	(29)
Fireweed (Epilobium angustifolium)		E.2,4-D	Water	3 ppa	FS	I	J. R. Thienes, Ext. Agent, Coos County, Oregon.
Gooseberry, Lobbs (Ribes lobbi)	No	2,4,5-T	Water	1.7 ahg	FS	I	(187)
		2,4,5-T	Oil or water	16.7 ahg	FS	I	
		2,4,5-T	Oil or water	16.7 ahg	CSS	I	
		2,4,5-T	Oil	41.7 ahg	BS	I	
Gooseberry, Blood Sierra (Ribes roezli, var. cruentum)	No	2,4,5-T	Water	1.7 ahg	FS	I	(187)
		2,4,5-T	Oil or water	16.7 ahg	CSS	I	
		2,4,5-T	Oil	41.7 ahg	BS	I	
Gorse (Ulex europaeus)	Yes	Mixed E.2,4-D & 2,4,5-T or E.2,4,5-T alone	Water	4 ahg	FS till plants are wet	II	(221)
		Ammate	Water	3 lbs./sq. rod (on small regrowth)	FS	II	(109)
		Sodium arsenite + borax	Water	2 lbs. sodium arsenite + 6 lbs. borax/ sq. rod	FS	I on small regrowth	

See footnotes on first page of table.

Table 1.--Chemical treatments for some Pacific Northwest brush species[1]--continued

Species	Sprouter [2]	Herbicide [3]	Diluent [4]	Concentration or rate [5]	Kind of application [6]	Degree of control [7]	Authority [8]
Hazel, California (Corylus cornuta var. californica)	Yes	2,4-D & 2,4,5-T mixed	DO	20 ahg	CSS	I	A. W. Smelser, Mt. Hood N. F.
		E.2,4-D	Water	4,000 ppm	DS	II	(10)
		E.2,4-D	Water	2,000 ppm	FS	I	
Incense-cedar (Libocedrus decurrens)	No	Mixed E.2,4-D & 2,4,5-T + 1% diesel oil	Water	2,000 ppm	FS	II or III	H. R. Offord, U. S. Forest Service, San Francisco.
Madrone, Pacific (Arbutus menziesii)	Yes	E.2,4-D	Water	10,000 ppm	CSS	I & II	(210)
Manzanita, greenleaf (Arctostaphylos patula)	Yes	E.2,4-D	Water	1-2 ppa	FS	95/90	(183)
Manzanita, hairy (Arctostaphylos columbiana)	No	E.2,4,5-T	Water 150 gal./A	1.53 ahg	FS	I (limited observation)	G. A. James, Port Orford Cedar Experimental Forest.
		A.2,4-D	Water 150 gal./A	4.9-7.4 ahg	FS	I & II	
Manzanita, pine (Arctostaphylos parryana var. pinetorum)	No	E.2,4-D	3 gal./A oil in water emulsion	1 ppa	FS	I	(60)

Manzanita, whiteleaf (Arctostaphylos viscida)	No	E.2;4-D	Water	2-3 ppa	FS	90/75	(183)
Manzanita, (Arctostaphylos species)		More susceptible to 2,4-D than 2,4,5-T					(55)
Maple, bigleaf (Acer macrophyllum)	Yes	Ammate crystals	None	None	CSC	IV	A.E. Thompson, Snoqualmie N. F.
Maple, vine (Acer circinatum)	Yes	Mixed E.2,4-D & 2,4,5-T	Water	2 ahg	FS	II or III	(216)
		Mixed E.2,4-D & 2,4,5-T	Water	1,500 ppm ea. chemical	FS	2nd application looks promising	(110)
Oak, California black (Quercus kelloggii)	Yes	Na. 2,4-D	Water 10 gal./ sq. rod	1,200 ppm	FS	III	(29)
Oak, canyon, live (Quercus chrysolepis)	Yes	Na.2,4-D	Water 10 gal./ sq. rod	1,200 ppm	FS	III	(29)
Oak, Oregon white (Quercus garryana)	Yes	Mixed 2,4-D & 2,4,5-T	K	20,000 ppm	CSS	I	(110)
Poison-oak, Pacific (Toxicodendron diversilobum)	Yes	A.2,4-D	2-1/2% DO in water emulsion	2.5 ahg	FS	100/87	(150)
		E.2,4,5-T	DO	4 ppa	FS	12/3	
		(Emulsive acid 2,4,5-T)	2-1/2% DO in water emulsion	(2.5 ahg) (2 ppa)	FS	100/98	

See footnotes on first page of table.

Table 1.--Chemical treatments for some Pacific Northwest brush species [1]--continued

Species	Sprouter [2]	Herbicide [3]	Diluent [4]	Concentration or rate [5]	Kind of application [6]	Degree of control [7]	Authority [8]
Raspberry, whitebark (Rubus leucodermis)		Sensitive to 2,4,5-T, not to 2,4-D					(135)
Rhododendron, coast (Rhododendron macrophyllum)	Yes	E.2,4,5-T	Water 100 gal./A	1.53 ahg	FS	I & II	G. A. James, Port Orford Cedar Experimental Forest.
Salal (Gaultheria shallon)	Yes	2,4-D & 2,4,5-T mixed + sticker spreader	Water	1,500 ppm ea. chemical	FS	II or III	(110)
Salmonberry (Rubus spectabilis)	Yes	Mixed E.2,4-D & 2,4,5-T	Water	1,500 ppm ea. chemical	FS	II	(110)
		Mixed E.2,4-D & 2,4,5-T	10 gal. DO 90 gal. water	3 ahg	FS	II but with a few spots of complete kill	D.H.Baisinger, Crown Zellerbach, Portland.
Sedges (Carex sp.)		E.2,4-D	90% water 10% DO	3 ppa	FS	I & II	J. R. Thienes, Ext. Agent, Coos County, Oregon.
		E.2,4-D	None stated	None stated	FS	III & IV	H. R. Offord, U. S. Forest Service, San Francisco.

Serviceberry, saskatoon (Amelanchier alnifolia)	Yes	E.2,4-D	Water	2 ppa	FS	I & II	1949 Annual Report North Central Weed Control Conference.
Silktassel, boxleaf (Garrya flavescens var. buxifolia)	Yes	A.2,4-D	Water 150 gal./A	7.4 ahg	FS	I & II	G. A. James, Port Orford Cedar Experimental Forest.
Snowberry, common (Symphoricarpos albus)	Yes	E.2,4-D	Water	1-1/2 ppa	FS	I & II	1950 Annual Report North Central Weed Control Conference.
Snowbrush (Ceanothus velutinus)	Yes	E.2,4-D w/ E.2,4,5-T	Water	Up to 24 ppa	FS	II or III	V. W. Dahlin, Rogue River N. F.
		E.2,4-D	3 gal./A oil in water emulsion	2 ppa	FS	II or III	(60)
Tanoak (Lithocarpus densiflorus)	Yes	E.2,4-D	Water	10,000 ppm	CSS	I	(210)
Thimbleberry, western (Rubus parviflorus)	Yes	E.2,4-D + 2,4,5-T	Water	4 ppa	FS	IV	J. R. Thienes, Ext. Agent, Coos County, Ore.
		E.2,4-D + 2,4,5-T	15 gal. DO	4 ppa	BS	One application reduced stand 40 to 50%	

See footnotes on first page of table.

Table 1.--Chemical treatments for some Pacific Northwest brush species[1]--continued

Species	Sprouter [2]	Herbicide [3]	Diluent [4]	Concentration or rate [5]	Kind of application [6]	Degree of control [7]	Authority [8]
Whortleberry, red (Vaccinium parvifolium)	Yes	Mixed E.2,4-D & 2,4,5-T	Water	1,500 ppm ea. chemical	FS	II or III	Pacific Telephone & Telegraph Company, Portland.
Willow, 2 species as follows:							
Bebb (Salix bebbiana) and	Yes	A.2,4-D	Water	750-1,125 ppm 2.68 ppa	FS first treatment on old mature trees	?/60	(224)
Coyote (Salix exigua)		A.2,4-D	Water	750-1,125 ppm 2.92 ppa	FS second treatment on sprouts	99/96	
Willow, Pacific (Salix lasiandra)	Yes	2,4-D		2 ppa	FS	I & II	(221)
Willow (Salix species)	Yes	E.2,4-D	Water	2 ahg	FS	I	Phil Hogen, Weyerhaeuser (Snoqualmie Falls Br.)

See footnotes on first page of table.

Table 2.--Common and scientific names of plants mentioned in the text of this publication

Common name	Scientific name
Alder, red	Alnus rubra
Ash, Oregon	Fraxinus latifolia
Aspen	Populus tremuloides
Barberry	Berberis species
Beech	Fagus grandifolia
Bitter cherry	Prunus emarginata
Blackberry	Rubus species
Blueberry, box	Vaccinium ovatum
Ceanothus	Ceanothus species
Chamise	Adenostoma fasciculatum
Chinkapin	Castanopsis species
Chokecherry, common	Prunus virginiana
Christmasberry (toyon)	Photinia arbutifolia
Elder (elderberry)	Sambucus species
Gooseberry, Sierra	Ribes roezli
Gorse	Ulex europaeus
Hazel	Corylus species
Juniper	Juniperus species
Kidneywort (coyote brush)	Baccharis pilularis
Loco	Astragalus species
Madrone, Pacific	Arbutus menziesii
Manzanita, greenleaf	Arctostaphylos patula
Manzanita, pine	Arctostaphylos parryana var. pinetorum
Maple, vine	Acer circinatum
Mesquite	Prosopis species
Mountain-laurel	Kalmia latifolia
Oak, blue	Quercus douglasii
Oak, California scrub	Quercus dumosa var. dumosa
Oak, canyon live	Quercus chrysolepis
Oak, interior live	Quercus wislizenii
Oak, shinnery	Quercus (several species)
Persimmon, common	Diospyros virginiana
Pine, Digger	Pinus sabiniana
Pine, eastern white	Pinus strobus
Pine, lodgepole	Pinus contorta

Table 2.--Common and scientific names of plants mentioned in the text of this publication--continued

Common name	Scientific name
Pine, ponderosa	Pinus ponderosa
Pine, western white	Pinus monticola
Poison-oak, Pacific	Toxicodendron diversilobum
Port-Orford-cedar	Chamaecyparis lawsoniana
Pricklypear	Opuntia species
Rhododendron, rosebay	Rhododendron maximum
Ribes	Ribes species
Salal	Gaultheria shallon
Sagebrush, sand	Artemisia filifolia
Sagebrush, big	Artemisia tridentata
Sagebrush	Artemisia species
Salmonberry	Rubus spectabilis
Saltbush, shadscale	Atriplex confertifolia
Sassafras	Sassafras albidum
Snakeweed, broom	Gutierrezia sarothrae
Snowbrush	Ceanothus velutinus
St. Johnswort, common (Klamathweed)	Hypericum perforatum
Tanoak	Lithocarpus densiflorus
Thimbleberry, western	Rubus parviflorus
Willow	Salix species

Table 3.--Effect of chemicals applied as foliage sprays on some Pacific Northwest conifers

Species	Herbicide 1/	Diluent	Concentration or rate 2/	Results and remarks	Authority 3/
Douglas-fir (Pseudotsuga menziesii)	E.2,4-D	Water 8 gal./A	2 ppa	Some bending of new leader.	(102)
	E.2,4-D	Diesel oil 8 gal./A	3.34 ppa	Considerable bending of new leader.	
	E.2,4,5-T	10% summer oil, 90% water. 10 gal./A	1 ppa	Almost no damage.	(65)
	E.2,4,5-T	Water 150 gal./A	3.0-4.6 ahg	Reproduction under 5 ft. considerably reduced in vigor; much killing of old needles and many branches at all concentrations.	G. A. James, Port Orford Cedar Experimental Forest.
	A.2,4-D	Water 150 gal./A	2.4-7.4 ahg	Reproduction under 5 ft. considerably reduced in vigor; much killing of old needles and many branches at all concentrations.	
	E.2,4,5-T + 2,4-D	Water 150 gal./A	3.28 ahg	Trees 3 ft. or less in height considerably reduced in vigor; much deadening of foliage, some killing of entire trees. Taller trees received only slight browning.	

1/ A (amine salt), E (ester).

2/ Ppa (pounds per acre), ahg (pounds acid equivalent per hundred gallons).

3/ Numbers refer to bibliography.

Table 3.--Effect of chemicals applied as foliage sprays on some Pacific Northwest conifers--continued

Species	Herbicide 1/	Diluent	Concentration or rate 2/	Results and remarks	Authority 3/
Hemlock, western (Tsuga heterophylla)	E.2,4-D	Water 8 gal./A	2 ppa	Very little damage.	(102)
	E.2,4-D	Diesel oil 8 gal./A	3.34 ppa	New growth killed back 2 or 3 years.	
	E.2,4,5-T	10% summer oil, 90% water. 10 gal./A	1 ppa	New leader growth affected more than ponderosa pine but seldom killed. Damage not serious.	(65)
Lodgepole pine (Pinus contorta)	E.2,4,5-T	90% H_2O 10% summer oil. 10 gal./A	1 ppa	New leader growth affected more than ponderosa pine but seldom killed. Damage not serious.	(65)
Ponderosa pine (Pinus ponderosa)	E.2,4-D	Water 100 gal./A	3.0 ahg	Trees thoroughly wet were killed. Brush overstory offered good protection to most trees.	(60)
	E.2,4,5-T	Water 100 gal./A	3.0 ahg	Trees thoroughly wet were killed. Brush overstory offered good protection to most trees.	
	E.2,4-D	Diesel oil 100 gal./A	3.0 ahg	Trees thoroughly wet were killed. Brush overstory offered poor protection.	
	E.2,4,5-T	Diesel oil 100 gal./A	3.0 ahg	Trees thoroughly wet were killed. Brush overstory offered poor protection.	
	E.2,4,5-T	90% H_2O 10% summer oil. 10 gal./A	1 ppa	New leader growth affected but seldom killed. Damage not serious.	(65)

Ponderosa pine (continued)	E.2,4-D	10% summer oil, 90% water. 10 gal./A	1 ppa	New leader growth affected. Damage light on most trees.	(60)
	E.2,4-D	1/3 summer oil, 2/3 water. 3 gal./A	2 ppa	Killing or serious crippling of exposed trees.	
Port-Orford-cedar (Chamaecyparis lawsoniana)	E.2,4,5-T	Water 150 gal./A	4.6 ahg	Trees less than 5 ft. tall not affected.	G. A. James, Port Orford Cedar Experimental Forest.
	A.2,4-D	Water 150 gal./A	2.4-7.4 ahg	Trees less than 5 ft. turned slightly brown at all concentrations.	
	E.2,4,5-T + 2,4-D	Water 150 gal./A	3.28 ahg	Trees less than 5 ft. slightly off color but vigor not reduced.	
Sugar pine (Pinus lambertiana)	A.2,4-D	Water 150 gal./A	2.4-7.4 ahg	Much killing of foliage. Many trees 3 ft. and less tall killed. Larger trees considerably browned and vigor reduced. No damage at lesser concentrations.	G. A. James, Port Orford Cedar Experimental Forest.
	E.2,4,5-T + 2,4-D	Water 150 gal./A	3.28 ahg	Same as above except no effect at lesser concentrations.	
Western white pine (Pinus monticola)	E.2,4,5-T	Water 150 gal./A	3.0-4.6 ahg	Much killing of foliage. Many trees 3 ft. and less tall killed. Only minor damage to larger trees. No damage at lesser concentrations.	G. A. James, Port Orford Cedar Experimental Forest.

See footnotes on first page of table.

Table 3.--Effect of chemicals applied as foliage sprays on some Pacific Northwest conifers--continued

Species	Herbicide 1/	Diluent	Concentration or rate 2/	Results and remarks	Authority 3/
Grand fir (Abies grandis)	E.2,4,5-T	90% H_2O 10% summer oil. 10 gal./A	1 ppa	New leader growth affected but seldom killed. Damage not serious.	(65)
Sitka spruce (Picea sitchensis)	E.2,4-D	Water 8 gal./A	2 ppa	Some bending of new leader	
	E.2,4-D	Diesel oil 8 gal./A	3.34 ppa	Considerable bending of new leaders. This species is about the most tolerant to chemicals of the Northwest conifers.	(102)

See footnotes on first page of table.

Table 4.--Approximate proportions of commercial product (containing 4 pounds of 2, 4-D or 2, 4, 5-T acid per gallon) required to prepare solutions or emulsions of desired concentrations [1]

Concentration by weight of acid			Concentration by volume of concentrate	Volume of product to make 1 gallon of solution		Volume carrier to add to 1 gallon of product
ppm [2]	percent	ahg [3]	percent	cubic centimeters	ounces	gallons
WATER CARRIER						
2,500	.25	2.1	.50	20	.67	200
5,000	.50	4.2	1.00	40	1.33	100
10,000	1.00	8.4	2.00	80	2.67	50
11,983	1.20	10.0	2.40	95	3.16	42
OIL CARRIER						
10,000	1.0	6.8	1.67	65	2.0	60
20,000	2.0	13.2	3.00	125	4.0	30
30,000	3.0	21.0	5.00	200	7.0	20
50,000	5.0	34.2	8.00	325	10.0	11
60,000	6.0	42.1	10.00	400	13.5	9

1/ From Chaiken (38) with some additions.

2/ Parts per million.

3/ Pounds, acid equivalent per hundred gallons.

Table 4 is helpful for mixing herbicides to a given concentration or for translating from one expression of concentration to another. Where the product being used contains 4 pounds acid equivalent per gallon, the amount needed for various concentrations is read directly from the table. For example, an emulsion containing 2, 500 ppm of

2, 4-D acid by weight in water can be made by adding 20 cubic centimeters or 0.67 of an ounce of the commercial product per gallon of water. It also shows that the desired emulsion can be obtained by mixing 1 gallon of the commercial product with 200 gallons of water. When the strength of the solution or emulsion is specified as a percentage of acid equivalent by weight, as so many pounds acid equivalent per hundred gallons, or as a percentage of volume of commercial concentrate, the table is used in a similar manner.

When the product used contains more or less than 4 pounds acid equivalent per gallon, a simple adjustment is needed. Had the concentrate contained only 3 pounds per gallon in the preceding example, the required amount would have increased to four-thirds of the amount shown in the table or from 20 to 27 cubic centimeters. Likewise, the amount of carrier required per gallon of commercial product is reduced to three-fourths of that shown in the table, or 150 gallons.

BIBLIOGRAPHY

Adams, Frank, Ewing, P. A., and Huberty, M. R. (1)
Hydrologic aspects of burning brush and woodland-grass ranges in California. Sacramento, Calif. Div. Forestry. 84 pp. 1947.

Akesson, Norman B. (2)
Recent investigations of spraying accessories: a progress report on nozzles. Calif. Weed Conf. Proc. 4: 58-64. 1952.

________ Spray drift. Calif. Weed Conf. Proc. 6: 69-71. 1954. (3)

________ and Harvey, W. A. (4)
Chemical weed control equipment. Calif. Agr. Expt. Sta. Cir. 389, 43 pp., illus. 1948.

Alway, F. J., and Rost, C. O. (5)
Effect of forest fires upon the consumption and productivity of the soil. First Internat. Cong. Soil Sci. Proc. and Papers 3: 546-576. 1928.

Anonymous (6)
Dalapon - a new systematic grass killer. Down to Earth 9 (3): 10-11, illus. 1953.

________ Dalapon - a new type of growth regulator effective on grasses. Dow Chemical Co. Dalapon Bul. No. 1. 10 pp. 1953. (7)

________ Pastures sprayed with weed killers safe for livestock. Down to Earth 6 (1): 11, illus. 1950. (8)

________ Picture and brief description of brush clearing machine. Oil and Gasoline Jour. 49 (11): 119, illus. 1950. (9)

________ U. S. Rural Elect. Admin. progress report on chemical brush control. 42 pp., illus. 1950. (10)

__________ TCA, its range of usefulness. Down to Earth 6 (1): 8-10, illus. 1950. (11)

__________ Silvex; a growth regulator effective in the control of woody plants and herbaceous broadleaf weeds. Dow Chemical Co. Silvex Tech. Bul. No. 1. 7 pp. 1954. (12)

__________ Weyerhaeuser continues aerial spraying. Timberman 54 (11): 151. Sept. 1953. (13)

Arend, J. L. (14)
Chemical frill girdling for control of undesirable hardwood trees. Lake States Clinic on Using Chemical Controls in Forest Management Proc. 1953: 30-34. (Lake States Forest Expt. Sta. Misc. Rpt. 21)

__________ Controlling scrub aspen with basal sprays. Down to Earth 9 (1): 10-11, illus. 1953. (15)

__________ and Coulter, L. L. (16)
Chemical frill girdling for pine release in Lower Michigan. Down to Earth 8 (4): pp. 2-4, illus. 1953.

__________ and Stephenson, Joseph R. (17)
Some costs and effects of chemical release of pine in northern Michigan. Lake States Forest Expt. Sta. Tech. Note No. 367, 1 p. 1952.

Arnold, Keith, Burcham, L. T., Fenner, Ralph L., and Grah, R. F. Use of fire in land clearing. Reprinted from Calif. Agr. V. 5, No. 3-7. 23 pp. illus. 1951. (18)

Aufderheide, Robert, and Morris, William G. (19)
Broadcast slash burning after a rain. West Coast Lumberman 75 (9): 79-83, illus. Also Fire Control Notes 10 (4): 1-6. 1949.

Barrons, Keith C. (20)
Some physiological aspects of the herbicidal action of DNOSBP. Down to Earth 7 (3): 10-12, illus. 1951.

Beatty, R. H. (21)
Chemical brush control--what it is. Lake States Forestry Clinic on Using Chemical Controls in Forest Management Proc. 1953: 1-7. (Lake States Forest Expt. Sta. Misc. Rpt. 21)

Beckley, M. S. (22)
Killing of trees and large brush by the basal chemical spray method. Calif. Weed. Conf. Proc. 5: 23. 1953.

Bickford, C. A., and Curry, John R. (23)
The use of fire in the protection of longleaf and slash pine forests. South. Forest Expt. Sta. Occas. Paper 105, 21 pp. 1943.

Bird, J. J. (24)
Practical land clearing on the Cumberland Plateau. Tenn. Agr. Expt. Sta. Bul. 198. 22 pp., illus. 1945.

Biswell, H. H. (25)
The brush control problem in California. Jour. Range Mgmt. 7 (2): 57-62, illus. 1954.

Blair, Byron O. (26)
Mesquite seed and seedling response to 2, 4-D and 2, 4, 5-T. Bot. Gaz. 112 (4): 518-521, illus. 1951.

Blaisdell, J. P. (27)
Effects of controlled burning on bitterbrush on the Upper Snake River Plains. Intermountain Forest & Range Expt. Sta. Res. Paper 20, 3 pp. 1950.

________ Ecological effects of planned burning of sagebrush-grass range on the Upper Snake River Plains. U. S. Dept. Agr. Tech. Bul. 1075, 39 pp., illus. 1953. (28)

Blanchard, Robert K. (29)
Killing brush with 2, 4-D. Fire Control Notes 8 (2 & 3): 13-17. 1947.

Bohmont, D. W. (30)
2,4-D in Wyoming. Wyo. Agr. Expt. Sta. Cir. 51. 16 pp., illus. 1953.

Brasington, James J. (31)
Pull - cut - or poison. Forest Farmer 7 (5): 14, illus. 1948.

Bruce, H. D. (32)
Chemical killing of sprouting stumps. Calif. Forest and Range Expt. Sta. Res. Note No. 23, 4 pp., illus. 1939.

Buchholtz, K. P., and Briggs, G. M. (33)
Weed control in field crops. Wis. Ext. Serv. Cir. 447, 12 pp. 1953.

Burns, P. Y. (34)
Effect of fire on forest soils in the pine barren region of New Jersey. Yale Univ., Sch. Forestry Bul. 57, 50 pp., illus. 1952.

California. Legislature. Assembly. Interim Committee on Agric. Public lands, grazing and forest practices; first progress report, Sacramento, Calif. 75 pp. 1952. (35)

Chaiken, L. E. (36)
Chemical control of inferior species in the management of loblolly pine. Jour. Forestry 49: 695-697. 1951.

________ The behavior and control of understory hardwoods in loblolly pine stands. Southeastern Forest Expt. Sta. Tech. Note 72, 27 pp. 1949. (37)

________ The use of chemicals to control inferior trees in the management of loblolly pine. Southeastern Forest Expt. Sta. Station Paper No. 10, 34 pp., illus. 1951. (38)

Chamberlin, Joseph C. (39)
Characteristics of airplane spray patterns at low flight elevations with relation to insect control. Paper delivered at National Aviation Trades Assoc. Aerial Applicator's Conf. 1953.

Clements, F. E. (40)
Plant succession and indicators. 453 pp., illus. New York. 1928.

Coldwell, Thomas, and Pechanec, J. F. (41)
The brushland plow. Pacific Northwest Forest & Range Expt. Sta. Res. Note 64, 7 pp., illus. 1950.

Conarro, Raymond M. (42)
The place of fire in southern forestry. Jour. Forestry 40: 129-131. 1942.

Cook, David B. (43)
A simple device for applying Esteron 245. Down to Earth 9 (3): 5, illus. 1953.

Cope, Joshua A., and Spaeth, J. Nelson. (44)
The killing of trees with sodium arsenite. Jour. Forestry 29: 775-783, illus. 1931.

Cornelius, Donald R., and Graham, Charles A. (45)
Selective herbicides for improving California forest ranges. Jour. Range Mgmt. 4 (2): 95-100. 1951.

Coulter, L. L. (46)
Silvex: a new selective herbicide for weed and brush control. Down to Earth 9 (4): 18-20. 1954.

________ Some aspects of right-of-way brush control with 2, 4, 5-T and 2, 4-D. Weeds 3 (1): 21-27. 1954. (47)

________ Two primary factors influencing results in the control of oak during the dormant period. Down to Earth 7 (4): 2-3, illus. 1952. (48)

________ Two primary factors influencing results in the control of oak during the dormant period. Lake States Forestry Clinic on Using Chemical Controls in Forest Management Proc. 1953: 26-29. (Lake States Forest Expt. Sta. Misc. Rpt. 21) (49)

Cox, Maurice B. (50)
Brush and tree removing machinery. Okla. Agr. Expt. Sta. Bul. B-310, 31 pp., illus. 1947.

Crafts, A. S. (51)
Absorption and translocation of herbicides. Annual Calif. Weed Conf. Proc. 5: 73-76. 1953.

__________ Chemistry of weed killers. Calif. Weed Conf. Proc. 3: 82-87. 1951. (52)

__________ General contact weed killers. Rev. ed. Calif. Agric. Ext. Serv. Circ. 137, 15 pp., illus. 1949. (53)

__________ Progress report on absorption and translocation of herbicides. Calif. Weed Conf. Proc. 6: 8-10. 1954. (54)

__________ and Leonard, O. A. (55)
Division of Botany - chemical brush control investigations. In California. Legislature. Assembly. Interim Committee on Agric. Public lands, grazing and forest practices; first progress report, pp. 40-41. 1952.

__________ and Harvey, W. A. (56)
The physiology of weed control. Western Weed Control Conf. Proc. 12: 61-69. 1950.

__________ and Stewart, D. N. (57)
Use of radioactive Isotopes of 2, 4-D in brush control. Western Weed Control Conf. Res. Prog. Rpt. 14: 131-134. 1954.

Crossley, D. I. (58)
Chemical thinning of young lodgepole pine stands. Canada Dept. of Resources and Development, Forestry Branch, Res. Div. Silvicultural Leaflet No. 42, 2 pp. 1950.

Currier, H. B. (59)
Wetting agents and other additives. Calif. Weed Conf. Proc. 6: 10-15. 1954.

Dahms, Walter G. (60)
Chemical brush control on central Oregon ponderosa pine lands. Pacific Northwest Forest & Range Expt. Sta. Res. Note No. 109, 5 pp. 1955.

Davis, Kenneth P., and Klehm, Karl A. (61)
Controlled burning in the western white pine type. Jour. Forestry 37: 399-407, illus. 1939.

Day, Maurice W. (62)
Chemical control of certain forest shrubs: a progress report. Mich. Agr. Expt. Sta. Quart. Bul. 30 (4): 427-436. 1948.

________ Controlling alder with basal sprays. Mich. Agr. Expt. Sta. Quart. Bul. 34 (4): 354-356. 1952. (63)

________ Hand sprayers. Lake States Clinic on Using Chemical Controls in Forest Management Proc. 1953: 40-42. (Lake States Forest Expt. Sta. Misc. Rpt. 21) (64)

DeJarnette, G. M. (65)
Tests of helicopter spraying for eradication of ribes. Northwest Science 27 (3): 107-113. 1953.

________ and Augenstein, J. W. (66)
Annual planting and nursery report. U. S. Forest Service, Region 1. 14 pp., illus. 1951.

Dingle, R. W.
The use of chemicals for the elimination of low-value species as a forest improvement measure. Mo. Agr. Expt. Sta. Prog. Rpt. 9. 29-32. 1950. (67)

Doutt, R. L. (68)
Biological control quarantine. Calif. Agr. 5 (9): 3, 14, illus. 1951.

Dudley, E. (69)
Comparison of an acid emulsive with other 2, 4-D formulations. Calif. Weed Conf. Proc. 5: 79-83. 1953.

Egler, Frank E. (70)
Herbicide effects in Connecticut vegetation, 1950. Jour. Forestry 50: 198-204, illus. 1952.

Elam, F. L. (71)
Goats cleared our brush. Western Livestock Jour. 30 (42): 37, 46, 51, 55, illus. June 1952.

Elwell, Harry M., and Cox, M. B. (72)
New methods of brush control for more grass. Jour. Range Mgmt. 3 (1): 46-51. 1950.

________ Brush control and pasture development research at the Red Plains Conservation Expt. Sta. Okla. Agr. Expt. Sta. Prog. Rpt. 6 pp. 1952. (73)

________ Experiments on brush control of hardwoods for grass production. Okla. Agr. Expt. Sta. Prog. Rpt. 8 pp. 1953. (74)

Emrick Walter E., and Leonard, Oliver A. (75)
Delayed kill of interior live oak by fall treatment with 2,4-D and 2,4,5-T. Jour. Range Mgmt. 7 (2): 75-76, illus. 1954.

Fisher, C. E. (76)
Control of woody plants with herbicides. Agr. Chem. 7 (3): 49, 115, 117-118. 1952.

________ The mesquite problem in the Southwest. Jour. Range Mgmt. 3 (1): 60-70. 1950. (77)

________ Some fundamental principles of brush control. Western Weed Control Conf. Proc. 13: 92-97. 1952. (78)

________, Phillips, Wm. M., Meadors, Jr., C. H., Darrow, R. A., and McCully, W. G. Mesquite control, cooperative ranch tests, 1950-51. Tex. Agr. Expt. Sta. Prog. Rpt. 1465, 10 pp. 1952. (79)

Flint, Knute (80)
Helicopters. Calif. Weed Conf. Proc. 2: 55-58. 1950.

Fowells, H. M., and Stephenson, R. E. (81)
Effect of burning on forest soils. Soil Sci. 38 (3): 175-181. 1934.

Freed Virgil H. (82)
Herbicides. 19 pp. (dittoed) July 27, 1953.

________ Weed control. Jour. Forest Products Res. Soc. 3 (2): 81-85. June 1953. (83)

________ Warren, Rex, and Leach, C. M. (84)
Selective weed control in grain and grass crops. Federal Coop. Ext. Serv. Oregon. Ext. Serv. Bul. 719. 31 pp., illus. 1951.

Frieberg, S. R., and Clark, H. E. (85)
Effects of 2, 4-dichlorophenoxyacetic acid upon the nitrogen metabolism and water relations of soybean plants grown at different nitrogen levels. Bot. Gaz. 113 (3): 322-333. 1952.

Friggens, Paul. (86)
Can we burn our brush? Farm Jour. 75 (2): 28-29, 94-96. 1951.

Gallup, Avery H., and Gustafson, Felix G. (87)
Absorption and translocation of radioactive 2, 4-dichloro-5-idio^{131}-phenoxyacetic acid by green plants. Plant Physiol. 27: 603-612. 1952.

Gertsch, Milton E. (88)
The influence of various carriers upon the inhibitory effectiveness of 2, 4-D sprays. Weeds 2 (1): 33-42. 1953.

Gieser, Arthur. (89)
The use of aircraft in application of agricultural chemicals. Western Weed Control Conf. Proc. 12: 36-41. 1950.

Glendening, George E. (90)
Thoughts on the juniper question. Ariz. Stockman 17 (2): 15, 30, 31, illus. 1951.

Gordon, D. T., and Cosens, Richard D. (91)
Slash disposal and site preparation in converting old-growth sugar pine-fir forests to regulated stands. Calif. Forest & Range Expt. Sta. Res. Note 81, 7 pp. 1952.

Gowen, George M. (92)
Highway hazard reduction guide. U. S. Forest Service in collaboration with State of Calif. Div. Forestry and Div. Highways. 56 pp., illus. 1950.

Grah, R. F., and Arnold, R. K. (93)
The use of fire as a land clearing tool. In California. Legislature. Assembly. Interim Committee on Agric. Public lands, grazing and forest practices; first progress report, p. 43-47. 1951.

Graham, Charles A. (94)
A practical way to evaluate spray distribution. Jour. Range Mgmt. 6 (4): 255-259, illus. 1953.

Hackett, David P. (95)
Experiments on the chemical control of hardwoods in northeastern forests. Northeast Weed Control Conf. Proc. 6: 311-319. 1952.

Hall, R. A.
Brush control with heavy machinery. Agr. Engin. 27 (10): 458. 1946. (96)

Halls, L. K. and Burton, G. W. (97)
Effect of 2, 4-D, 2, 4, 5-T and sodium trichloroacetate on gallberry. Jour. Forestry 49: 895-897, illus. 1951.

Hamilton, L. S. (98)
Power brush saws make thornapple removal easier. Genesee County Farm Bureau News, 36 (9): 2, illus. 1953.

Hansen, Henry L. (99)
A test of ground application of 2,4-D under hazel brush (*Corylus* sp.). Res. Rpt. 8th Annual North Central Weed Control Conf. 1951.

Hartman, H. J., and Offord, H. R. (100)
The eradication of poison-oak at Camp Adair, Oregon. Jour. Forestry 45: 105-112, illus. 1947.

Harvey, W. A., and Robbins, W. W. (101)
2,4-D as a weed killer. Calif. Agr. Ext. Serv. Cir. 133. 12 pp., illus. 1947.

Hawkes, Carl. (102)
Planes release tree plantation. Jour. Forestry 51: 345-348, illus. 1953.

Hedrick, D. W. (103)
Brushland management in California. Jour. Range Mgmt. 4 (3): 181-183. 1951.

__________, Biswell, H. H., and Schultz, A. M. (104)
Response of brush seedlings to sprays of 2,4-D and 2,4,5-T on burned chamise areas. Calif. Fish and Game 39 (4): 497-505. 1953.

Helgeson, E. A., and Widdifield, R. B. (105)
Chemical control of perennial weeds. N. Dak. Agr. Col. Ext. Serv. Cir. A-194, 5 pp. 1953.

Herman, F. R. (106)
Use of ammate crystals for poisoning ponderosa pine in stand improvement. Rocky Mountain Forest & Range Expt. Sta. Res. Note 14, 5 pp. 1954. Similar information in: Use of "Ammate" for poisoning ponderosa pine in stand improvement. Jour. Forestry 47: 966-967. 1949.

Heyward, Frank. (107)
Soil temperatures during forest fires in the longleaf pine region. Jour. Forestry 36: 478-491. 1938.

__________, and Barnette, R. M. (108)
Effect of frequent fires on chemical composition of forest soils in the longleaf pine region. Fla. Agr. Expt. Sta. Bul. 265, 39 pp., illus. 1934.

Hill, D. D. (109)

Gorse control. Oreg. Agr. Expt. Sta. Cir. of Information 450, 10 pp., illus. 1949.

Hoff, William S. (110)

Experiments in chemical control of brush on telephone lead right-of-way in the State of Oregon. Down to Earth 8 (1): 5-7, illus. 1952.

Hoffman, Otto L, and Sylwester, E. P. (111)

Comments: On quack grass control with maleic hydrazide. Weeds 2 (1): 66-67. 1953.

Holloway, J. K., and Huffaker, C. B. (112)

The role of _Chrysolina gemellata_ in the biological control of Klamath weed. Jour. Econ. Ent. 44 (2): 244-247. 1951.

Hough, A. F. (113)

Weed killers may be useful in reforesting old burns. Northeastern Forest Expt. Sta. Northeastern Res. Note 1, 4 pp. 1950.

Huckenpahler, B. J. (114)

Axe or poison? Southern Lumberman 185(2321) 180-182, illus. 1952.

Hull, A. C., Jr., Kissinger, N. A., Jr., and Vaughn, W.T. (115)

Chemical control of big sagebrush in Wyoming. Jour. Range Mgmt. 5 (6): 398-402, illus. 1952.

__________, and Vaughn, W. T. (116)

Controlling big sagebrush with 2,4-D and other chemicals. Jour. Range Mgmt. 4 (3): 158-164. 1951.

__________, and Doran, Clyde W. (117)

Observations on equipment and methods for brush control. Fort Collins, Colo. Rocky Mountain Forest & Range Expt. Sta. 5 pp. (mimeo.) 1950.

Hyder, Donald N. (118)

Controlling big sagebrush with growth regulators. Jour. Range Mgmt. 6 (2): 109-116. illus. 1953.

Ibberson, Joseph E., and Egler, Frank E. (119)
Right-of-way maintenance by the selective application of selective herbicides. Penn. Forests and Waters 3: 114-115, 125. Nov./Dec. 1951.

Ikenberry, G. J., Bruce, H. D., and Curry, John N. (120)
Experiments with chemicals in killing vegetation on firebreaks. Jour. Forestry 36: 507-515. 1938.

Isaac, L. A., and Hopkins, H. G. (121)
The forest soil of the Douglas fir region, and changes wrought upon it by logging and slash burning. Ecology 18: 264-279.

Jankowski, E. (122)
Some brush control problems needing attention. Lake States Clinic on Using Chemical Controls in Forest Management Proc. 1953: 43-45. (Lake States Forest Expt. Sta. Misc. Rpt. 21)

Jordon, G. L., and Freed, V. H. (123)
Brush control in western Oregon. Western Weed Control Conf. Res. Prog. Rpt. 13: 59-60. 1952.

Kelso, S. R. (124)
Regulating the application of sprays and dusts. Oreg. Dept. Agr. Bul. 174: 18-19. 1952.

Kissinger, N. A., Jr. and Hurd, Richard M. (125)
Control big sagebrush with chemicals and grow more grass. Rocky Mountain Forest & Range Expt. Sta. Station Paper No. 11, 23 pp. 1953.

Kittredge, Joseph (126)
Stabilization of soil in the management of northern California brushfields. Ann. Mtg. Northern Calif. Soc. Amer. Foresters. pp. 36-40 (processed). 1948.

Kotok, E. I. (127)
Fire, a problem in American forestry. Sci. Monthly 32 (8): 3. 1930.

LaFaver, L. H., and Hamblet, J. F. (128)
Brush removal by chemical treatment. U. S. Forest Serv., Region 1. 13 pp. (mimeo.), illus. 1951.

Larson, William H. (129)
Airplane spraying for weed trees. Western Forestry and Conservation Assoc. Proc. 43: 46-47. 1952.

________ Forest roadside control of alder and willow. Jour. Forestry 49: 705-707. 1951. (130)

Lauterbach, Paul G. (131)
Aerial brush spraying in the Douglas fir region and other recent developments in the use of aircraft in industrial forestry. Tacoma, Wash. Weyerhaeuser Timber Co. 6 pp. 1953.

________ 1952 Clemons aerial brush spraying experiment. Summary and results of the 1953 examination. Tacoma, Wash. Weyerhaeuser Timber Co. Forestry Res. Notes. 6 pp. 1953. (132)

Lavender, Denis P. (133)
A preliminary report on tree planting as a gorse control measure. Oreg. State Board Forestry Res. Note 11, 10 pp., illus. 1953.

Lemon, Paul C. (134)
Prescribed burning in relation to grazing in the longleaf-slash pine type. Jour. Forestry 44: 115-117. 1946.

Leonard, Oliver A. (135)
Chemical brush control techniques. Calif. Agr. Expt. Sta. 8 pp. (mimeo.) 1952.

________ Chemical eradication of brush species. Calif. Weed Conf. Proc. 3: 61-68. 1951. (136)

________ Effect of some oils and silicones on the sensitivity of bean plants to the propylene glycol butyl ether ester of 2, 4-D. Western Weed Control Conf. Res. Prog. Rpt. 14: 130-131. 1954. (137)

_____ High volume application of herbicides to sprouting and seedling chamise. Calif. Weed Conf. Proc. 5: 43-53. 1953. (138)

_____ New developments in woody plant control with chemicals. Calif. Weed Conf. Proc. 6: 43-46. 1954. (139)

_____ Project 4. Undesirable woody plants of forest and range land. Western Weed Control Conf. Res. Rpt. 1953: 22-23. (140)

_____ Recent results on the chemical control of woody plants on California range lands. Western Weed Control Conf. Res. Prog. Rpt. 14: 44-45. 1954. (141)

_____ Western Weed Control Conf. Res. Prog. Rpt. 13: 73. 1952. (142)

_____ Result of cut-surface experiment on interior live oak. Western Weed Control Conf. Res. Prog. Rpt. 13: 53-54. 1952. (143)

_____ Results of a test on the chemical control of chamise sprouts (Adenostoma fasciculatum) and seedlings. Western Weed Control Conf. Res. Prog. Rpt. 13: 51-53. 1952. (144)

_____ Undesirable woody plants on irrigation systems, forest and range lands. Western Weed Control Conf. Res. Prog. Rpt. 14:25. 1954. (145)

_____, and Carlson, C. E. (146)
Chemical brush control techniques on California range lands. Calif. Dept. Natural Resources, Div. Forestry. 7 pp., illus. 1953.

_____, and Jackson. (147)
Western Weed Control Conf. Res. Prog. Rpt. 14: 48. 1954.

__________ and Lusk. (148)
Western Weed Control Conf. Res. Rpt. 13: 73, 74, 79. 1952.

____
Western Weed Control Conf. Res. Prog. Rpt. 14: 47. 1954. (149)

__________, and Osborn. (150)
Western Weed Control Conf. Res. Prog. Rpt. 14: 54. 1954.

Little, S. (151)
Prescribed burning as a tool of forest management in the Northeastern States. Jour. Forestry 51: 496-500. 1953.

____
Prescribed burning in New Jersey and Maryland. N. Y. State Univ., Col. Forestry, State Ranger School Alumni News. pp. 18, 21, 26, illus. 1952. (152)

__________, Allen, J. P., and Moore, E. B. (153)
Controlled burning as a dual-purpose tool of forest management in New Jersey's pine region. Jour. Forestry 46: 810-819. 1948.

__________, Somes, H. A., and Allen, J. P. (154)
Choosing suitable times for prescribed burning in southern New Jersey. Northeastern Forest Expt. Sta. Station Paper 51, 7 pp. 1952.

Love, R. Merton, and Jones, Burle J. (155)
Improving California brush ranges. Calif. Agr. Expt. Sta. Circ. 371. 38 pp., illus. 1952.

Lyman, Robert A., and Sykes, Walter E. (156)
The Johnston chain drag for clearing brush from range land. Jour. Range Mgmt. 7 (1): 31-32, illus. 1954.

MacBride, J., Capell, J. E., Cathie, W., Kaufmann, D. R., and Bunting, A. H. Mechanized land clearing - a survey of four years' experience in Tanganyika. World Crops 3 (3): 89-94, illus. 1951. (157)

Manuel, M. O. (158)
Aerial application of chemical herbicides. Lake States Forestry Clinic on Using Chemical Controls in Forest Management Proc. 1953: 37-40. (Lake States Forest Expt. Sta. Misc. Rpt. 21)

Martin, S. Clark (159)
Apparent kill of persimmon and sassafras by application of 2, 4-D and 2, 4, 5-T. Central States Forest Expt. Sta. Tech. Paper 132, 8 pp., illus. 1952.

__________, and Clark, F. Bryan (160)
Controlling hardwood sprouts with foliage sprays. Central States Forest Expt. Sta. Tech. Paper 145, 10 pp. 1954.

McCartney, J. (161)
Power sprayers for chemical herbicides. Lake States Forestry Clinic on Using Chemical Controls in Forest Management Proc. 1953: 34-37. (Lake States Forest Expt. Sta. Misc. Rpt. 21)

McIlvain, E. H. (162)
Shinnery oak is yielding to 2, 4-D. Down to Earth 8 (4): 6-7. illus, 1953.

__________, and Savage, D. A. (163)
Fifteen year summary of range improvement studies by the Bureau of Plant Industry at the U. S. Southern Great Plains Field Station, Woodward, Okla.

McNamora, J. J. (164)
Chemical control of brush. Calif. Agr. 5 (7): 5, 11. July, 1951.

McQuilkin, W. E. (165)
Bulldozer better than poisons for preparing scrub oak planting sites. Northeastern Forest Expt. Sta. Northeastern Res. Note 7, 4 pp. 1951.

Meadors, Cecil H., Jr., and Fisher, C. E. (166)
Absorption and translocation of 2, 4-D and 2, 4, 5-T when applied to the bark of mesquite stems. Western Weed Control Conf. Res. Prog. Rpt. 14: 141. 1954.

Melander, L. W. (167)
Control of woody plants. North Central Weed Conf. Res. Rpt. 7:227-270. 1950.

______ Summary of informal discussion on spraying woody plants in the dormant stage. Lake States Forestry Clinic on Using Chemical Controls in Forest Management Proc. 1953: 21-25. (Lake States Forest Expt. Sta. Misc. Rpt. 21) (168)

Merchant, L. G. (169)
A new brush cutter. Amer. Cattle Producer 31 (10): 10, 13, 31. 1950.

Mitchell, John W., Dugger, W. M., and Gauch, H. G. (170)
Increased translocation of plant-growth-modifying substances due to application of boron. Sci. 118 (3065): 354-355. Sept. 25, 1953.

Mobley, Lowell, Talbert, M. W., and Pryor, Murray A. (171)
Western Weed Control Conf. Res. Prog. Rpt. 14: 47. 1954.

Morrison, Vance L. (172)
Chemical spray for protection roads. Jour. Forestry 48 (6): 429-430. 1950.

______ Roadside strip clearing on fire protection roads for western Oregon. Oreg. State Board Forestry Res. Bul. No. 4, 11 pp. 1949. (Preliminary Report) (173)

Morrow, Robert R. (174)
Dormant silvicide treatment of aspen and beech. Down to Earth 9 (2): 13-15, illus. 1953.

Moss, V. D. (175)
Developments in chemical methods of Ribes suppression in the white pine forests of Washington, Idaho and Montana during 1953. Western Weed Control Conf. Res. Prog. Rpt. 14: 27-28. 1954.

__________, and Wellner, Charles A. (176)
Aiding blister rust control by silvicultural measures in the western white pine type. U. S. Dept. Agr. Cir. 919, 32 pp., illus. 1953.

__________, Quick, C. R., et al. (177)
Developments in chemical methods of Ribes suppression in the Western States during 1952. Western Weed Control Conf. Res. Rpt. 1953: 28-29.

Mullison, W. R. (178)
The effect of droplet size upon herbicidal effectiveness of plant growth regulators. Down to Earth 9 (2): 11-13, illus. 1953.

Myler, J. L., and Street, J. E. (179)
Brush range improvement. Calif. Agr. 5 (9): 5, 14, illus. 1951.

Neuns, Alva G. (180)
Woody plant control along roads in Shasta National Forest. Down to Earth 8 (1): 14-15, illus. 1952.

__________, and Simpson, Albert. (181)
The use of 2, 4-D and 2, 4, 5-T for brush control on California roads and trails. Berkeley, Calif. Calif. Forest & Range Expt. Sta. 31 pp., illus. 1953.

Offord, H. R. (182)
Killing ribes with 2, 4-D and 2, 4, 5-T. Jour. Range Mgmt. 2(4): 201-205. 1949.

____
Western Weed Control Conf. Res. Prog. Rpt. 14: 52, 58. 1954. (183)

____
Western Weed Control Conf. Res. Rpt. 13: 76. 1952. (184)

__________, Van Atta, G. R., and Swanson, H. E. (185)
Chemical and mechanical methods of ribes eradication in the white pine areas of the Western States. U. S. Dept. Agr. Tech. Bul. 692, 50 pp., illus. 1940.

__________, and Voss, C. M. (186)
Fogging ribes, white pine and brush with 2, 4-D by helicopter. Weeds 1 (1): 61-69. 1951.

__________, Moss, V. D., Benedict, W. V., Swanson, H. E., and London, A. Improvements in the control of ribes by chemical and mechanical methods. U. S. Dept. Agr. Cir. 906. 72 pp., illus. 1952. (187)

Page, G. E. (188)
Weed spraying equipment. Oreg. Agr. Expt. Sta. Bul. 493, 24 pp., illus. 1951.

Pardee, G. C. (189)
Forestry in the state-wide water plan. Sacramento, Calif. Dept. Natural Resources, Div. Forestry. 22 pp. 1932.

Parker, Kenneth W. (190)
Control of mesquite on Southwestern ranges. U. S. Dept. Agr. Leaflet 234, 8 pp., illus. 1943.

__________, and Martin, S. Clark. (191)
The mesquite problem on Southern Arizona ranges. U. S. Dept. Agr. Circ. 908, 70 pp., illus. 1952.

Pattengale, P. S., and Miller, M. D. (192)
Chemical control of brush. Calif. Agr. 4 (7): 3, 5. July 1950.

Paulsen, Harold A., Jr. (193)
Mortality of velvet mesquite seedlings. Jour. Range Mgmt. 3 (4): 281-286, illus. 1950.

Pearse, C. Kenneth. (194)
New trends in control of noxious range plants. Jour. Forestry 49: 498-500, illus. 1951.

Pechanec, Joseph F. (195)
Machinery for clearing brush lands. Grassland Congress, 6th, Proc. 2: 1279-1284. 1952.

__________, and Stewart, George. (196)
Sagebrush burning - good and bad. Rev. ed., U. S. Dept. Agr. Farmers' Bul. 1948. 34 pp., illus. 1954.

__________, Fisher, C. E., and Parker, K. W. (197)
How to control noxious plants. U. S. Dept. Agr. Yearbook (Grass): 256-260. 1948.

Peevy, Fred A. (198)
New poisons for undesirable hardwoods. Jour. Forestry 49: 450. 1951.

__________, and Grano, C. X. (199)
ABC's of hardwood control. New Orleans, La. South. Forest Expt. Sta. 4 pp., illus. 1952.

Pickett, J. (200)
Coyote brush control in San Mateo County. Calif. Farmer (North Edition) 191: 394-395. 1949.

Playfair, L. (201)
Effect of chemicals on woody growth. Western Canadian Weed Control Conf., 5th Proc. and Abstr. 1951.

Pryor, Murray R. (202)
The spray drift problem. Annual Calif. Weed Conf. Proc. 3: 114-117. 1951.

Reigner, Irvin C. (203)
Do not plant trees too soon after using weed killers. Northeastern Forest Expt. Sta. Northeastern Res. Note 20: 3-4. 1953.

Rigdon, Harry P. (204)
Eradication of trees and shrubs. Okla. Ext. Serv. Cir. 526. 10 pp. 1951.

Robbins, Wilfred W., Crafts, Alden S., and Raynor, Richard N. Weed control 2nd Edition. 503 pp., illus. New York. 1952. (205)

Roe, Eugene I. (206)
Foliage spraying in chemical brush control. Lake States Forestry Clinic on Using Chemical Controls in Forest Management Proc. 1953: 17-21. (Lake States Forest Expt. Sta. Misc. Rpt. 21)

Rudolf, Paul O. (207)
Chemical control of brush and tree growth for the Lake States. Lake States Forest & Range Expt. Sta. Misc. Rpt. 15, 30 pp. 1951.

________ The place of chemical controls in forest management. (208)
Lake States Forestry Clinic on Using Chemical Controls in Forest Management Proc. 1953: 8 - 12. (Lake States Forest Expt. Sta. Misc. Rpt. 21)

Sampson, A. W. (209)
Plant succession on burned chaparral lands in northern California. Calif. Agr. Expt. Sta. Bul. 685, 144 pp., illus. 1944.

Schubert, G. H. (210)
Control of sprouting tanoak and madrone stumps. Calif. Forest & Range Expt. Sta. Res. Note 74, 2 pp. 1950.

Shantz, H. L. (211)
Use of fire as a tool in management of brush ranges of California. Calif. Div. Forestry. 156 pp. 1947.

Shipman, R. D. (212)
Poisoning small-diameter hardwoods with the Cornell tool. Southeastern Forest Expt. Sta, Res. Note 38. 2 pp. 1953.

Somes, H. A., and Moorhead, G. R. (213)
Prescribed burning does not reduce yield from oak-pine stands of southern New Jersey. Northeastern Forest Expt. Sta. Station Paper 36, 19 pp. 1950.

Stoeckler, Joseph H., and Heinselman, M. L. (214)
The use of herbicides for the control of alder brush and other swamp shrubs in the Lake States. Jour. Forestry 48: 870-874. 1950.

Stone, E. C., and Juhren, G. (215)
The effect of fire on the germination of the seed of Rhus ovata Wats. Amer. Jour. Bot. 38 (5): 368-372, illus. 1951.

Strege, Bob (216)
Chemicals prove effective in brush control. Lumberman 80 (2): 58-59, 106. 1953.

Suggitt, J. W. (217)
Dormant season brush control is easier and more effective. Electrical World 137 (18): 89-91, illus. May 5, 1952.

Swain, Lewis C. (218)
Economical tree killing. New Hampshire Agr. Expt. Sta. Bul. 408. 15 pp., illus. 1954.

Tannehill, Glen F. (219)
Control of hardwood underbrush by bulldozing. Jour. Forestry 49: 776-778, illus. 1951.

Tarrant, R. F. (220)
Effect of heat on soil color and pH of two forest soils. Pacific Northwest Forest & Range Expt. Sta. Res. Note 90, 5 pp. 1953.

Thienes, John R. (221)
1953 weed spray chart, Coos County. Ext. Agent, Coos County, Oregon. 2 pp. (mimeo.)

Tillyard, R. J. (222)
The biological control of noxious weeds. Fourth Internat. Cong. Ent. Trans. 2: 4-9. 1928.

Timmons, F. L., and Lee, W. O. (223)
Chemical control of chokecherry. Res. Comm. Western Weed Control Conf. 1953: 38-39.

———— Western Weed Control Conf. Res. Prog. Rpt. 14: 49, 60. 1954. (224)

Tuckett, A. J. (225)
Practical control of gorse. New Zealand National Weed Conf. Proc. 4: 10-14. 1951.

Upchurch, M. L. (226)
Oregon's capacity to produce. Oreg. Expt. Sta. Bul. 459. 20 pp. 1948.

U. S. Forest Serv., Calif. Forest and Range Expt. Sta. (227)
Annual report - 1951. 53 pp. 1952.

U. S. Forest Serv., Southwestern Forest and Range Expt. Sta. Annual report 1950. 62 pp., illus. 1951. (228)

____
Annual report 1952. 65 pp., illus. 1953. (229)

__________, and U. S. Soil Conservation Service (230)
Influences of vegetation and watershed treatment on run-off, silting, and stream flow. U. S. Dept. Agr. Misc. Pub. 397, 80 pp., illus. 1940.

Wahlenberg, W. G., and Doolittle, W. T. (231)
Reclaiming Appalachian brush lands for economic forest production. Jour. Forestry 48: 170-174. 1950.

Warren, Rex and Freed, Virgil. (232)
Evergreen, Himalaya and wild blackberry. Oregon State Col. Ext. Bul. 570. 8 pp., illus. 1950.

Whitworth, S. E. (233)
Sagebrush control in Beaverhead County. Mont. Wool Grower 26 (11): 24-26. Nov. 1952.

Wiksten, Ake (234)
1953 aerial brush spraying project. Tacoma, Wash., Weyerhaeuser Tbr. Co. Forestry Res Notes. 5 pp. 1953.

Wright, Ernest (235)
The effect of high temperatures on seed germination. Jour. Forestry 29: 679-687. 1931.

Young, Dale W., and Fisher, C. E. (236)
Factors affecting absorption and translocation of herbicides in mesquite. Western Weed Control Conf. Proc. 12: 41-48. 1950.

Young, Vernon A., et al. (237)
Recent developments in the chemical control of brush on Texas ranges. Texas Agr. Expt. Sta. Bul. 721, 18 pp. 1950.

Zappettini, George. (238)
A study of the ecology and control of Halogeton glomeratus in Idaho. A thesis, presented in partial fulfillment of requirements for degree of Master of Science in Forestry, Univ. Idaho. 1952.

Zehngraff, Paul, and von Bargen, John. (239)
Chemical brush control in forest management. Jour. Forestry 47: 110-112. 1949.

INDEX TO BIBLIOGRAPHY

Reference Numbers

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Dear Sir:

This will call your attention to an error in our Research Paper 13 "Brush control on forest lands," by Walter G. Dahms and George A. James, which was distributed last June. We will appreciate it if you will insert the following changes in your copy.

Page 26, last paragraph should read:

Biological control, especially of insects that damage agricultural crops, has received considerable attention. C. P. Clausen (39A) reported in 1952 that a total of more than 600 species of parasites and predators had been imported into the continental United States during the past 60 years, and that approximately 100 species of insects had become successfully established in various parts of the country. Relatively few attempts have been made, however, to control noxious plants through the introduction of specific insects. Control of common St. Johnswort (Klamathweed) by a species of *Chrysolina* is one of the most notable examples in the United States. Other outstanding examples reported by Robbins and collaborators (205) include control of pricklypear in Australia by *Cactoblastis cactorum* and control of a thorny shrub in the Hawaiian Islands.

Page 57. The following reference should be added at the top of the page:

Clausen, C. P. (39A)
Biological control of insects. Calif. Agric. 6(11): 10. 1952.

Sincerely yours,

R. W. Cowlin

R. W. COWLIN
Director